A Study of the Meat Products Industry Through Systems Analysis and Simulation of Decision Units

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A RESEARCH PROCEDURE has long been needed for concurrent study of individual parts of an industry and the industry as a whole. Some researchers have isolated a segment of the industry and explored it in great detail; but they have failed to place it in perspective with other parts of the industry. Other researchers have studied the industry as an aggregate without identifying cause-and-effect relationships.

In this article, the livestock-meat industry is examined from the systems analysis standpoint by focusing on the interrelationships and interactions among the various parts of the industry. A model of the meat-products industry is presented that involves the use of a series of subsystems to represent a sequence of events characterizing the industry. Because of the size and complexity of the model, the program was written in FORTRAN and solved on a digital computer.

The analytical model was first constructed and tested to determine whether it adequately represented and reproduced the workings of the industry. Next, by making selected changes in the model or data and then obtaining a new set of results, the effects of each change were simulated. When these two sets of results--the basic run and the simulation runs--were compared, each difference obtained was viewed as a direct effect of the change made in the simulation run.

Model Construction

Data used in the model represented 2 percent of the firms in the Iowa meat-products industry.[1] The fundamental model design could be

adapted for use in other geographic areas and in the study of other industries.

The meat-products industry was defined as including all groups and activities involved in the movement and processing of livestock from the producer to the consumer: Producers, livestock markets, slaughterers, processors, wholesalers, retailers, and households. Within each of these groups were a number of individual decision units.

The model used the individual decision units as the essential elements in the interrelationships and interactions of the industry. The model included program sequences to reconstruct and complete transactions between decision units. These sequences were represented by a series of equations depicting purchases, sales, bargaining arbitration, and levels of production and demand.

Several decision criteria were used to determine the price and quantity in each transaction. Other decision criteria were used to determine whether firms should enter or leave the industry. In addition, preference functions were used to select transaction partners. Provision was also made in the program to use historical data in current decisions. Finally, the program allowed a specific sequence or process to be repeated for several weeks.

Model Details and Examples

The processor and slaughterer were combined in the model developed because these functions are often combined in the industry and because it was desired to reduce the number of groups in the program.[2] The scaling of the model to

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[1] Lawrence A. Duewer, Market Simulation of Economic Behavior in the Meat-Products Industry, unpublished Ph.D. thesis, Iowa State Univ. Sci. and Tech., Ames, Iowa, 1965.

[2] When reference is made to the real world, rather than the model, the term "industry" is used.

depict 2 percent of the Iowa industry and the use of representative households, livestock markets, and producers were decisions required to comply with computer storage capacity and to reduce machine running time. The representative decision units in the model used the multiple values in table 1 to keep quantities consistent among groups of decision units. Provision was also made to allow shipments of meat from Iowa.

Table 1.--Groups and decision units used in the model

Group	Number of decision units used	Multiple value	2 percent of Iowa
Households................	60	280	16,800
Retailers.................	20	1	20
Wholesalers.............	5	1	5
Processor-slaughterers...	4	1	4
Livestock markets........	4	4	16
Producers................	16	100	1,600

The transaction and decision arrangements in the model were completed for a 1-week period. This period was selected to represent demand decisions realistically. Consumers usually shop at least once each week; retailers, wholesalers, and processor-slaughterers also make many of their decisions on a weekly basis. The program can be continued for several weeks. The basic run was completed for 8 consecutive weeks and the simulation runs for 4 weeks each. These time periods were about the minimum that could be used to obtain sufficient information concerning changes throughout the industry.

Three meat classes were included in the model: Pork, beef, and other meat. "Other meat" included poultry and all red meats except pork and beef.

A diagram of the model used to represent the meat-products industry is shown in figure 1. A livestock producer may sell direct to a processor-slaughterer located either near a terminal or in the interior. He may also sell through a terminal market or to a local dealer. The producer's preference of livestock market
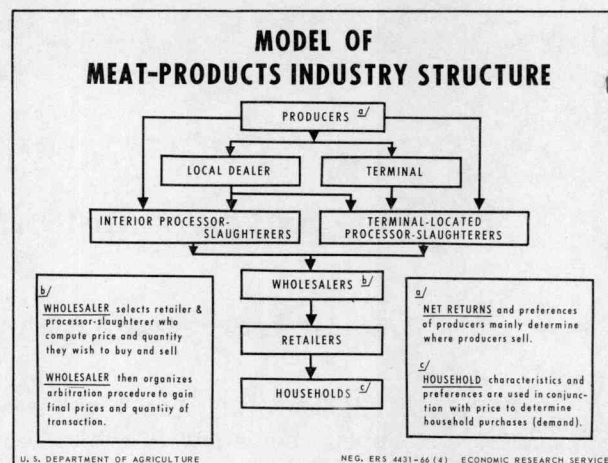

MODEL OF MEAT-PRODUCTS INDUSTRY STRUCTURE

Figure 1

is determined by a preference equation of the form:

$$(1) \qquad Y_t = a + b_1 X_{1,t} + b_2 X_2 + b_3 X_3 + A$$

where

Y_t = the preference index value held by the producer this week for this livestock market,

$X_{1,t}$ = the price, in dollars per pound, offered the producer this week at this livestock market,

X_2 = the distance in miles this producer is from this livestock market,

X_3 = an index value of the attitude this producer has toward this livestock market, and

A = the constant value of 0.2 if this producer sold to this livestock market last week and 0.0 if he did not.

A unique solution is obtained for each producer in relation to each livestock market. The market yielding the highest value for this producer is where the livestock is sold. Preference equations are used in the model whenever a decision unit desires to transact business and needs a transaction partner.

If the producer sells through a terminal, the animals are sold to a processor-slaughterer located at a terminal. The local dealer may resell his purchases to a processor-slaughterer located either in the interior or at the terminal market.

The wholesaler acts as an organizer of transactions between retailers and processor-slaughterers. In the model he selects a retailer and a processor-slaughterer on the basis of his preference function. Each of the selected businessmen takes into account the relevant supply and demand conditions, to determine the price he wishes to pay or receive and the quantity he wishes to buy or sell.

Operationally, the wholesaler then checks to see if the retailer is willing to pay enough more than the processor-slaughterer price to repay the costs incurred by the wholesaler. In addition, a check is made to see if the retail quantity desired is equal to or more than the amount the processor-slaughterer wants to sell this retailer. If either result is negative, the processor-slaughterer is allowed to revise his price and quantity and the wholesaler completes the checks again. If the checks still are not both positive, the retailer is allowed to revise his price and quantity and the wholesaler makes the check once more. If the results are not equal or positive at this point, the sale is completed with the prices desired by each firm, using the processor-slaughterer's quantity. The wholesaler thus may not obtain the margin desired. If the results are equal or positive at any point, the transaction is confirmed. To illustrate, the first retail price equation is of the form:

$$(2) \quad P_t = a + b_1 X_{1, t-1} + b_2 X_{2, t-1} + b_3 X_{3, t}$$

where

P_t = the price at which this retailer wishes to purchase this meat class through this wholesaler this week,

$X_{1, t-1}$ = the price paid by this retailer for this meat class last week,

$X_{2, t-1}$ = the price charged to his customers by this retailer for this meat class last week, and

$X_{3, t}$ = the quantity of this meat class that this retailer wants to purchase through this wholesaler this week.

The household group provides the final demand for meat products. For a given week, the prices to the consumer do not change, but consumers can indicate their approval or disapproval by the quantities they purchase at the prices charged. The demand relationships used, including the relevant variables, are presented in figure 2.
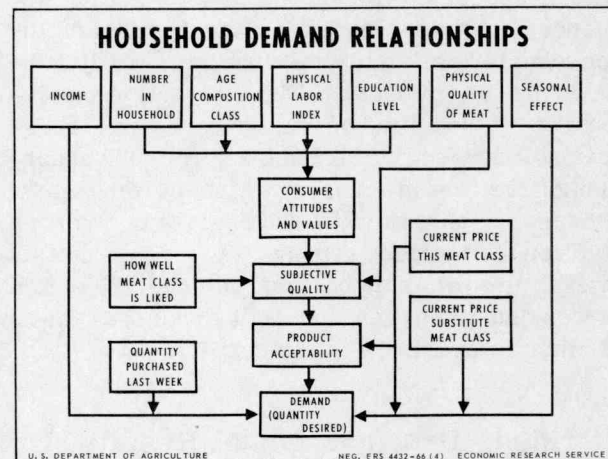

Figure 2

An additional example is presented to indicate the technique used for making decisions. The decision criterion selected is the test to see if the household has purchased at least a minimum quantity of all meat combined. This is represented by a FORTRAN statement of the form:

$$(3) \quad \text{IF (TMETC(IC))} - B70) \ 179, 178, 178$$

where

TMETC (IC) = total pounds of all meat classes purchased by this household and

B70 = minimum quantity (5 pounds) required to be purchased by each household.

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Thus, the statement tests whether the amount purchased (TMETC(IC)) is greater than the amount required (B70). If the subtraction is negative, insufficient meat is purchased and the program continues by moving to program statement 179 where the order quantities are revised. If as much or more meat than the minimum required is purchased, the program moves to the next household's computations (program statement 178).

The model begins with the retailer, wholesaler, processor-slaughterer transaction sequence; it next determines the results of the household-retailer interactions; and finally, the sales by the producers. The interaction involving the wholesaler, acting to carry out transactions between the retailer and the processor-slaughterer, was chosen to begin the model because it appears to be the basic or controlling position for price setting. The result of this interaction of supply and demand to obtain prices and quantities then influences the results of other interactions in the system.

Meat-Products Model Results

The results of the basic run provide a test of the model. They also provide a standard for comparison with results obtained from the simulation runs. The entire set of values obtained in the basic run would require many tables. We therefore show here only the names of the main variables, by industry segment, for which results were obtained:

Consumers:
    Price to consumer
    Quantity each consumer purchases
    Product acceptability index

Retailers:
    Price retailer pays
    Amount each retailer buys
    Amount each retailer sells
    Retailer inventory levels

Wholesalers:
    Quantities each wholesaler handles
    Wholesaler profits

Processor-slaughterers:
    Price processor-slaughterer receives
    Price paid by processor-slaughterer
    Quantity each processor-slaughterer buys
    Quantity each processor-slaughterer sells
    Processor-slaughterer inventory levels

Livestock markets:
    Price livestock market pays producer
    Net price received by livestock market
      when selling to processor-slaughterer
    Quantity purchased by each livestock market

Producers:
    Net price received by producer
    Computed minimum price producer will
      accept
    Amount each producer sells

Miscellaneous:
    Various totals
    Entry and exit of firms
    Preference values and behavior indexes

The value for each of the variables is computed for each decision unit in the group, for each meat class, and for each model week. Table 2 presents the average pork price levels of all decision units in the group for five price variables for the 8 weeks of the basic run.

Table 2.--Pork price levels, in dollars per pound, at various stages in the industry, by weeks

Variable	Week							
	1	2	3	4	5	6	7	8
Price to consumer......	0.455	0.493	0.487	0.485	0.486	0.492	0.495	0.498
Price retailer pays....	.391	.385	.383	.386	.389	.391	.395	.383
Price Processor-slaughterer receives.	.324	.330	.339	.325	.337	.353	.336	.317
Price paid by proc-essor-slaughterer....	.297	.295	.299	.298	.295	.296	.302	.297
Price livestock market pays producer........	.290	.287	.291	.290	.288	.289	.293	.289

The information in table 2, along with the rest of the basic run results, illustrates the kind of results obtained by the model. These findings seem consistent with actual industry levels.

The following changes were made to provide seven simulation runs:

1. Increased production by 10 percent.

2. Increased consumer demand by 10 percent.

3. Changed retailer advertising to stress pork.

4. Increased each consumer's income $1,000 per year.

5. Changed the pattern of attitudes by the producer toward livestock markets.

6. Increased the minimum price the producer would accept by 5 cents per pound for pork and 2 cents per pound for beef and other meat.

7. Increased the levels of all historical data 10 percent.

These changes indicate the type of conditions that can be studied. The directions of change observed are as expected, considering economic principles and practices of the industry. For example, the production increase caused prices to decrease, and the increase in consumer incomes caused meat consumption to increase. In some cases, however, the magnitude of the change was small. For instance, the increase in consumer demand did cause the price to the consumer to increase, but only by about 0.2 cent per pound. Several current trends in the industry are supported by the study results: for example, the decrease in the number of retailers and the increase in retailer size.

Conclusions

The example discussed indicates that a systems analysis approach that involves the simulation of individual decision units can be used to realistically represent the meat-products industry. However, further refinement of this type of model and improvements in the data are needed to further examine the workings of the meat-products industry. With appropriate changes in the model, this type of analysis could be applied to other industries. For instance, different industry groups would be required, but the transaction sequences between decision units would be similar.

The procedures discussed in this article provide a method of examining both the entire industry and the various subsystems within the industry. The use of simulation in conjunction with a systems analysis model provides a laboratory for testing possible changes.