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A model of the monthly structure of the U.S. beef-pork economy

Thomas E. Elam

To the Graduate Council:

I am submitting herewith a dissertation written by Thomas E. Elam entitled "A model of the monthly structure of the U.S. beef-pork economy." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Charles Sappington, Major Professor

We have read this dissertation and recommend its acceptance:

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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February 1973

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We have read this dissertation
and recommend its acceptance:

James Snell

Tongzone Lee

Charles M Cuskaden

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

A MODEL OF THE MONTHLY STRUCTURE OF THE U. S. BEEF-PORK ECONOMY

A Dissertation

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

Thomas E. Elam

March 1973

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ABSTRACT

The principal aim of this study was to develop a simultaneous equation model of the U. S. beef-pork economy. Also, postsample period changes in selected endogenous variables were analyzed.

Five theoretical and eleven statistical equations were specified. Using two stage least squares the statistical equations were fitted to monthly data of January 1964 through December 1970.

It was found that the most important variables affecting cattle and hog marketings were respective inventory levels. Prices paid by packers for cattle and hogs were strongly influenced by respective wholesale prices.

Changes in cold storage of beef and pork were influenced by respective production levels, first of month inventories and prices.

Wholesale to retail marketing margins for the two meats responded to changes in retail food store wage rates.

Retail demand was inelastic for beef and pork, but appeared to be elastic for broilers. No firm statement could be made about the elasticity of broiler demand, as price was used as the dependent variable. Beef and pork were very weak substitutes at the retail level.

Results of the postsample analysis were, for the most part, disappointing. The first stage equations of the model were used to calculate values for endogenous variables from actual data on exogenous variables. It was found that these calculated values were not

outstandingly successful in tracking changes in respective actual values. The model did predict levels of all endogenous price variables would rise between February 1971 and February 1972, although in some cases it missed the extent of the rises by a considerable amount.

In addition, it was found that published cattle inventories, but not published hog inventories, were useful for tracking postsample data. From a summary table of elasticity estimates from past studies, it would appear that retail demand for beef is becoming more price and income inelastic. For this and other recent studies, the income elasticity for pork was positive, a result which contradicted earlier studies.

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CHAPTER I

INTRODUCTION

I. OVERVIEW OF THE BEEF AND PORK MARKETING SECTOR

Expenditures on beef and pork at the retail level in the United States comprise no small proportion of total food expenditures. In fact, in 1969 about 30.8 percent of each dollar spent on food went for these two commodities. Put in a different perspective, expenditures for the two meats in the same year accounted for some 5.3 percent of total private personal consumption (U.S.D.A., 1969, pp. 309, 315, 459; U. S. Department of Commerce, 1971, p. 308). Clearly, Americans consider these two meats as important parts of their everyday diets.

Beef and pork markets in the United States have historically displayed relatively large price movements at all marketing levels during rather short time periods. The primary reason for this instability is that observed aggregate beef and pork output is the result of independent decisions made by a great number of cattle and hog producers. The quantity of the two meats produced changes as producers react to market stimuli, giving rise to changes in beef and pork prices. These interacting changes in beef and pork output and prices have been the subject of numerous research efforts. Such efforts have resulted in a reasonably consistent list of the relevant determinants of output and price changes as well as estimates of their importance. Many of these studies, however, included only farm and retail prices thus taking the marketing sector as given.

Recently, the marketing sector itself has come under more scrutiny. Rather than take this sector as given, attention has been focused on the impact of market structure on retail meat prices. Studies of the marketing sector are demand oriented while those of farmer reaction are mostly supply oriented.

Studies which focus primarily on the marketing sector do not take supply as strictly given, although the view is quite close to that. These studies, almost of necessity, have very short time units of observation; e.g., one month. The view is that while potential output for any month is predetermined by past actions of producers, that portion actually marketed in any month is determined by circumstances in that month; i.e., the farm producer has some latitude in the timing of the marketings. Producers can sell from inventory or hold for sale in a subsequent month depending upon market conditions, particularly current animal prices and expected near future animal prices. Interacting with these producer decisions packers' demand for market animals is in turn derived from the wholesale and retail demand for beef and pork.

This study is concerned with the marketing structure for beef and pork as it relates to prices and quantities at several levels of sale. A focal point will be the controversial price rises in retail meat during the first four months of 1972 which brought considerable attention to the beef and pork marketing system. During this period, producer, packer, retailer and consumer groups all stated that they could not be "blamed" for the increase. One purpose of this study is to investigate these rises in meat prices. It may be true that no one group is responsible and that all share the "blame".

II. OBJECTIVES

There are three principal objectives for this study. They are:

1. To estimate a monthly simultaneous equation model of the U. S. beef-pork sector including (a) marketing patterns of cattle and hog producers, (b) the demand behavior of packers with respect to cattle and hogs, (c) the behavior of wholesale to retail marketing margins, and (d) direct price, cross price, and income elasticities for both beef and pork at the retail level.

2. To use the estimated model in calculating values for retail prices of beef and pork beyond the data used for estimation to ascertain if price rises for retail beef and pork which took place during this period were the outcome of a structure which previously existed.

3. To test the usefulness of recently begun U.S.D.A. data series of cattle on feed and of inventories of market hogs, in explaining variations in quantity marketed of cattle and hogs.

III. SUMMARY OF PAST RESEARCH

The U. S. livestock industry has been the subject of a considerable amount of economic research. In order to establish a frame of reference for this study, several of these past efforts will be reviewed and summarized. Studies included in this section constitute major efforts at analyzing the short term structure of the cattle-hog sector using econometric models. Thus, those reviewed are in no way representative of all studies which have dealt with the meat industry.

The Myers Study

Myers' simultaneous monthly model (Myers, 1968) concentrated heavily on the hog-pork sector but also included, for completeness, cattle-beef and broiler relationships. The primary objective was to estimate the structure of the hog-pork economy with a secondary objective to development of a short term prediction model.

His model consisted of eight simultaneous equations which were normalized with respect to slaughter supply of live hogs, slaughter supply of live cattle, farm to retail margin for pork, farm to retail margin for beef, pork supply for consumption, retail pork demand, retail beef demand, and retail broiler demand. Data including months of 1949-1966 were used to estimate the model.

Myers' argument for a simultaneous system of supply and demand for cattle and hogs versus a recursive system (see Harlow, 1962) is based upon the possibility of holding or not holding finished animals depending on the costs of holding versus gain from holding. That is, when farmers have the capability of altering intermonthly marketing patterns in the face of continually changing current information then simultaneity is likely to exist.

Of particular interest was Myers' development of a theoretical model of monthly slaughter animal supply. He assumed that the quantity of animals of slaughter weight at the beginning of a month plus the quantity reaching slaughter weight during the month are predetermined by past production decisions. However, the quantity and average weight of animals actually supplied for slaughter depend upon expected revenue from carry-over versus expected cost of carry-over. Quantity (in pounds) supplied for slaughter for a given month may thus be stated as a function of present farm level price, expected farm level price, costs of carry-over, and number of animals of slaughter weight.

Empirical slaughter supply equations estimated with this model incorporated only one price variable--current farm price. The estimated coefficients for price in these equations were negative in sign. This unusual result was rationalized on the basis that the current price variable also reflected expected price, thus the estimated coefficients were the sum of current and expectational forces. Myers noted that a rise in expected price would lead to reduced current marketings, whereas, a similar movement in current price would lead to a rise in current marketings, _ceteris paribus_. The fact that both estimated market supply price variables were negative was taken as an indication that the former effect dominated, that is, expectational effects of a price change were larger than current effects.

The Hayenga and Hacklander Study

A study by Hayenga and Hacklander (1970) focused on farm level demand for cattle and hogs. The variables explained were live cattle price, live hog price, pork cold storage, cattle supply, and hog supply. Monthly data for the period 1963-68 were utilized.

Results of this study indicated that cattle and hog prices at the packer level were responsive to quantities slaughtered of both animals, personal income, and season of the year expressed as (0,1) intercept dummy variables for months. In the case of variations in hog prices, level of and change in pork cold storage were also found to be important. Quantity of beef was found to have an unexpected positive effect on the price of hogs.

Intramonthly change in cold storage stocks of pork was found responsive to quantity of hogs slaughtered, price of hogs, beginning inventory of cold storage, and season of the year expressed as (0,1) dummy variables for months.

Quantity supplied of cattle and hogs was found to respond to their respective prices and inventory levels. Price of hogs was found to have an unexpected negative influence on quantity supplied. The authors concluded that:

> One possible explanation for the direction of producer response is the idea that hog producers expect the most recent price trend to be continued. Consequently, they may sell less in the current month because they believe prices will continue to increase if they have been doing so in the very recent past [Hayenga and Hacklander, 1970, p. 543].

Of interest was the authors' development of monthly cattle and hog inventory models based on quarterly data. The procedure adopted was to utilize slope change (interaction) dummy variables to allow for different impacts of quarterly inventory levels for the second and third months following a quarterly report. The authors did not allow for intercept changes among all months of a year, but rather only among quarters.

The Tomek Study

In a study by Tomek (1965) quarterly data were utilized to estimate retail demand equations for beef, pork, and poultry. The principal aim here was to determine what, if any, changes had occurred over time with respect to direct price flexibilities and elasticities of the three meats.

Data were divided into two subperiods, 1949-1956 and 1956-1964, with separate sets of equations estimated for each subperiod.

There was little change in measured flexibilities and elasticities between the two periods although estimated regression coefficients of the equations for each subperiod were significantly different. This apparent contradiction was explained by the form of the equations estimated and the method of computing flexibilities and elasticities. Since a linear model was utilized the author computed flexibilities and elasticities at the subperiod data means. The changes in these means between the two periods offset changes in coefficients thus resulting in nearly constant flexibilities and elasticities.

Seasonal (quarterly) variations were handled by the use of (0,1) intercept dummy variables without the use of slope change terms; that is, constant slopes were assumed among quarters. This assumption is realistic in the light of earlier work.[1]

The retail price elasticities for beef, pork and broilers for the period 1956-1964 were computed as -.90, -.90, and -2.33, respectively.

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[1] See for example, Logan and Boles (1962), Stanton (1961), and Farris and Darley (1964).

The Farris and Darley Study

A single equation demand model of broiler prices was formulated by Farris and Darley (1964). In the equation broiler prices were regressed on broiler, beef, and pork supplies and also income.

The principal conclusion of the study was that quarterly or yearly aggregation of the model's monthly data resulted in significant changes in estimated intercept coefficients, but not significant changes in estimated slope coefficients. The price elasticity for broilers was about -1.1.

The Harlow Study

Harlow's model, a recursive system, was constructed on the basis of the following chain of causation: (1) sows farrowing as a function of lagged sows farrowing, and lagged prices of hogs, corn, and beef; (2) hogs slaughtered as a function of lagged sows farrowing; (3) pork production as a function of hogs slaughtered and pigs saved; (4) cold storage holdings of pork as a function of lagged production and lagged cold storage of pork; (5) retail price of pork as a function of production of pork, cold storage of pork, production of beef and broilers, income, quarterly dummy variables, and season, based on mean quarterly temperatures; and (6) farm level price of hogs as a function of retail price of pork, marketing changes, and season.

The Stanton Study

In an analysis of beef, pork, and broiler prices by Stanton (1961) quarterly data were combined into two seasons: (1) "winter" consisted of the fourth and first quarters, and (2) "summer" consisted of the second and third quarters. Separate demand equations were specified for each season and compared with respect to estimated regression coefficients. Quantity consumed of beef, pork, and broilers was expressed as a function of the prices of the three meats and income in the three demand equations.

The author concluded that:

> Seasonal movements in retail prices of beef and pork cannot be explained by changes in supply or consumption alone. This indicates that the demand for each meat is not stable throughout the year but differs seasonably in a definite pattern [Stanton, 1961, p. 14].

The author tempers these results somewhat by pointing out the arbitrary nature of the seasonal divisions. Specifically, he states that combining of the second and third quarters into the same season for beef "obscured some of the differences that appeared to exist originally" (Stanton, 1961, p. 14).

<u>The Fuller and Ladd Study</u>

Fuller and Ladd (1961) constructed a quarterly model of the beef-pork sector. Single equation methods were utilized based on the assumption that quantities supplied by farmers, and thus wholesale prices, may be taken as predetermined in a time period as short as a quarter.

The model consisted of: (a) two consumer demand equations, (b) two cold storage equations, (c) two farm to wholesale marketing margin equations, and (d) two wholesale to retail marketing margin equations.

Variables affecting retail prices of the two meats were consumption and lagged consumption of the two meats as well as income. Variables affecting cold storage levels of beef and pork were quantities of beef and pork marketed, lagged cold storage, and season expressed as a dummy variable. Variables entering the two farm to wholesale marketing margin equations were quantities marketed, wholesale prices and lagged margins. Variables in the two wholesale to retail marketing margin equations were wholesale prices, retail wage levels, and lagged margins.

Thus, this model takes the form of a recursive system with lagged dependent variables appearing on the right-hand side. A method developed by Fuller and Martin (1961) for dealing with such equations was used in the estimation process.

A purpose of their study was the estimation of the dynamic structure of the beef-pork sector—thus, the inclusion of lagged dependent variables in all equations. The authors concluded, however, that in most of the estimated equations long run, or dynamic, price flexibilities were not significantly different from respective estimated short run flexibilities.

CHAPTER II

THE MODEL

I. OVERVIEW OF THE MODEL

The model to be developed in this section is based, in general, on the assumptions of profit and utility maximization inherent in conventional microeconomic theory (see for example, Ferguson, 1969). In brief, this model may be stated in terms of eleven interdependent behavioral equations, ten identities, and two market clearing equations. The behavioral equations explain variations in (are normalized on):

1. Quantity of cattle marketed by farmers
2. Quantity of hogs marketed by farmers
3. Packer level price of cattle
4. Packer level price of hogs
5. Change in cold storage of beef
6. Change in cold storage of pork
7. Wholesale to retail marketing margin for beef
8. Wholesale to retail marketing margin for pork
9. Retail demand for beef
10. Retail demand for pork
11. Retail demand for broilers

The ten identities define: (a) expected change in price of cattle, (b) expected change in price of hogs, (c) quantity of carcass beef produced, (d) quantity of wholesale pork cuts produced, (e) change in cold storage of beef, (f) change in cold storage of pork, (g) wholesale to retail marketing margin for beef, (h) wholesale to retail marketing margin for pork, (i) quantity of beef consumed, and (j) quantity of pork consumed. The two market clearing equations set equal quantities supplied and demanded for cattle and hogs, respectively.

Shown in considerable detail below are the behavioral equations and the variables which enter them, with the identities and market clearing equations being discussed last.

For all behavioral equations a general, or theoretical, model will be presented followed by specific, or statistical models for each meat. In conjunction with the statistical models variables are defined in terms of sources from which the data for this study were taken.

The time period selected for the study covers the months from January 1964 through December 1970. Relative to other studies of this nature, this constitutes a rather short period. However, this is justified on the basis that one goal of this study was to arrive at a set of coefficients which would reflect the near past structure of the beef-pork sector.

II. FARM LEVEL SUPPLIES OF MARKET CATTLE AND HOGS

Theoretical Farm Level Market Supply Equation

Equations explaining variations in the monthly supplies of market cattle and hogs are taken from the Myers study (1968) discussed in Chapter I. Central to the Myers model is the assumption that inventory of market animals is predetermined within a given month, whereas marketings are not; that is, producers have the option of selling market animals or holding them over in inventory for sale in a succeeding month.

This allocation between sale and holding is regulated by current price relative to expected price in the near future,[1] the desire to avoid holding an animal until it becomes overweight and thus less marketable, and the costs of holding in inventory, primarily feeding costs.

The function for the farm level supply relationship for month i and year j may be written (omitting subscripts i and j)[2] as:

$$Q^{*s} = f(P^{*e\Delta}, I, P_f)$$

where

Q^{*s} = liveweight quantity, in pounds, supplied to market,

$P^{*e\Delta}$ = expected change in liveweight price,

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[1]In the Myers study the short term rate of interest was included to discount expected price. The appropriate short term rate, that is, the short term real rate of interest, is fairly constant, and for this reason was excluded from the present study as being largely unimportant as a modifier of expected price.

Another, and perhaps more important departure from Myers' equations involves the specific form taken by the price variable. Myers allows the coefficient for current price to be the summation of current month effects and expectational effects. Negative estimated coefficients for price in supply equations for cattle and hogs were justified by Myers on the basis that expectational effects dominate. This study argues that expected price depends upon more than current price, and can in fact be given an empirical (though approximate) definition.

Since in the short run cattle or hog producers should not be concerned with actual level of price, but rather movement of price, it was decided that the difference between expected price and actual price, representing expectation of short run price movements, would be used as the endogenous price variable rather than two separate price variables, one for actual price and one for expected price.

[2]This convention will be observed throughout the study in order to keep the notation as compact as possible.

I = inventory of slaughter weight animals, and

P_f = price of feed.

In this notation an asterisk denotes that a variable is jointly determined, or endogenous. Other variables are assumed to be predetermined.

Statistical Farm Level Market Supply Equations

Applying this model to derive equations to explain variations in quantities of cattle and hogs marketed involves defining the model's variables in terms of empirical data. Two variables which appear in the theoretical equation for quantity marketed do not have readily apparent data sources. The first of these is expected change in price ($P^{*e\Delta}$), which, by its very nature, is unobservable. Values for this variable were generated from cattle and hog prices in a manner described in the discussion of identities (a) and (b) below. Also, there is no known suitable published data series on monthly cattle or hog inventories (I).

Statistical estimates of cattle on feed are published by U.S.D.A. for six states on a monthly basis. However, preliminary analysis indicated that this series does not adequately represent changes in inventories of cattle for the entire nation. U.S.D.A. also publishes cattle on feed statistics for a twenty-three state area. This latter source represents nearly all cattle being fed for market, however, it is on a quarterly basis. For the present study it was decided to exploit the quarterly data, utilizing slope and intercept dummy variables to account for effects in the three month period between quarterly reports. A somewhat similar inventory model was used by Hayenga and Hacklander (1970).

Also, for ten major hog producing states U.S.D.A. publishes quarterly statistical estimates of the number of market hogs on farms. These will be exploited in a manner similar to that utilized for cattle inventories using slope and intercept dummy variables to allow for impacts between quarterly reports.

Time trend (T) was added to the two statistical market supply equations to account for any cost reducing, thus output increasing, technological trends in cattle and hog production. Examples of such trends include, in the case of cattle production, the increasing use of automated feedlots and, in hog production, trends toward specializations in feeder and market animal production. The estimated coefficients for this variable will give an indirect measure to the impact of such innovations upon quantity marketed of cattle and hogs.

It is recognized that feed priced (P_f) include more than corn, the commodity in which this variable is defined in terms of for present purposes. However, as prices of feed grains tend to move together over time, it is not thought that this definition of the variable is any serious limitation.

In the notation of equation (1) below and similar equations which follow, β denotes that a coefficient is a parameter of a predetermined variable while γ denotes a parameter for an endogenous variable. Subscripts for coefficients are interpreted as parameter number and equation number. Thus, $\gamma_{1.2}$ denotes the coefficient for the first endogenous variable appearing in the second equation. More than one parameter is necessary in the statistical equations for the inventory variable (I). Here an addition was made to the above notational scheme such that $\beta_{1.1.2}$ represents, again, the first predetermined variable appearing in the first equation with the 2 denoting that this is the second parameter for this variable.

In order to differentiate variables in the statistical equations as to the meat being discussed and its stage in the marketing process, subscripts c and h will be used for cattle and hogs, respectively, while b, p, and br refer to beef, pork, and broilers, respectively. Superscript pc is used for variables defined on a per capita basis.

In equation (1) below, and in subsequent statistical behavioral equations, it is assumed that the correct algebraic form is one which is linear in the variables.

The statistical equation for supply of market cattle is:

$$Q_c^{*s} = \beta_{0.1} + \gamma_{1.1} P_c^{*e\Delta} + \beta_{1.1.1} I_c + \beta_{1.1.2} S2 + \beta_{1.1.3} S3 + (\beta_{1.1.4} \text{ through } \beta_{1.1.14}) M + \beta_{2.1} P_f + \beta_{3.1} T + e_1 \quad (1)$$

where

Q_c^{*s} = commercial cattle slaughter, millions of pounds liveweight, 48 states (U.S.D.A., 1971),

$P_c^{*e\Delta}$ = expected change in the price of cattle, as defined in identity (a) below,

I_c = cattle and calves on feed, millions of head, 23 states, quarterly data (U.S.D.A., 1971), reported on the first of January, April, July, and October,

S2 = slope change dummy variable for second month after a quarterly report on I_c (S2 = I_c for February, May, August, and November observations, 0 otherwise),

S3 = slope change dummy variable for the third month after a quarterly report on I_c (S3 = I_c for March, June, September and December observations, 0 otherwise),

M = a block of 0,1 dummy variables for months with January being deleted to avoid singularity,

P_f = price of #3 yellow corn (\$/bu.) at Chicago (U.S.D.A., 1964-1972; U.S.D.A., 1970-1972),

T = time trend, that is, the 84 months of the study numbered consecutively, 1 through 84, and

e_1 = the stochastic error term associated with this equation.

The statistical equation for supply of market hogs is:

$$
\begin{aligned}
Q_h^{*s} = {} & \beta_{0.2} + \gamma_{1.2} P_h^{*e\Delta} + \beta_{1.2.1} I_{h,60\text{-}119} + \beta_{1.2.2} I_{h,120\text{-}179} \\
& + \beta_{1.2.3} I_{h,180\text{-}219} + \beta_{1.2.4} S2_{60\text{-}119} + \beta_{1.2.5} S2_{120\text{-}179} \\
& + \beta_{1.2.6} S2_{180\text{-}219} + \beta_{1.2.7} S3_{60\text{-}119} + \beta_{1.2.8} S3_{120\text{-}170} \\
& + \beta_{1.2.9} S3_{180\text{-}219} + (\beta_{1.2.10} \text{ through } \beta_{1.2.20})\, M \\
& + \beta_{2.2} P_f + \beta_{3.2}\, T + e_2 \qquad (2)
\end{aligned}
$$

where

Q_h^{*s} = commercial hog slaughter, millions of pounds liveweight, 48 states (U.S.D.A., 1971),

$P_h^{*e\Delta}$ = expected change in price of hogs, as defined by identity (b) below,

I_h = hogs on farms being kept for market, millions of head, 10 states, for three weight classes (U.S.D.A., 1971), reported on the first of December, March, June, and September,

S2 = slope change dummy variables for each of the three weight classes for the second month after a quarterly report on I_h (i.e., $-S2_{60-119} = I_{h,60-119}$ for January, April, July, and October observations, 0 otherwise),

S3 = slope change dummy variables for each of the four weight classes for the third month after each quarterly report on I_h (i.e., $-S3_{60-119} = I_{h,60-119}$ for February, May, August, and November observations, 0 otherwise), and

M, P_f and T are as previously defined.

Assuming profit maximizing behavior on the part of cattle and hog producers, the signs of the parameters of the variables of equations (1) and (2) can be given *a priori* expectations.

If expected change in liveweight price ($P_c^{*e\Delta}$ or $P_h^{*e\Delta}$) is positive producers would reduce marketing in the current month in order to increase marketings in the ensuing month, *ceteris paribus*. Therefore, it is expected that $\gamma_{1,1}$ and $\gamma_{1,2}$ are negative.

As the inventory of cattle on feed (I_c) rises, the number of cattle supplied (Q_c^*) should also rise. That is, it is expected that $\beta_{1.1.1}$ is positive.

In order to arrive at the slope coefficients for cattle inventory in the second or third months following the beginning of a quarter the coefficient of S2 or S3 must be added to $\beta_{1.1.1}$, respectively. The coefficients for these slope change dummy variables cannot be given *a priori* expectations. However, it would be expected that an increase in inventory of all cattle on feed at the beginning of a quarter would result in increased marketing for all months of that quarter, *ceteris paribus*. That is, it would be expected that the sums of the coefficients for I_c and S2 or S3 would be individually positive.

Separate slope shift dummy variables were included in the hog supply equation for different weight class inventory levels. This was done in order to allow these classes to have different effects on quantity supplied during a given quarter. That is, the coefficients for this equation will give (among other things) the pattern of hog marketings with respect to the three inventoried weight classes, with the classes allowed to have different effects through time. Thus, if hogs in the 60-119 pound weight class at the beginning of a quarter are market ready three months later, the impact of this class is allowed to be negative in month 1 of the quarter and positive in month 3.

No specific *a priori* statements will be made with respect to the expected signs of the hog inventory variables' coefficients or their respective slope change coefficients. However, it is expected that these will in general follow the pattern of heavier weight classes being marketed early in the quarter and lighter weight classes being marketed later.

As the price of feed (P_f) rises, costs of holding market animals in inventory also rise, *ceteris paribus*. Thus, a rise in the price of feed would result in a rise in current marketings, *ceteris paribus*. It is then expected that $\beta_{2.1}$ and $\beta_{2.2}$ are positive.

It is expected that the coefficients for time in these two equations ($\beta_{3.1}$ and $\beta_{3.2}$) will be positive. This is based upon the trends in cattle and hog production toward lower cost, more specialized methods which should lead to higher levels of marketings, *ceteris paribus*.

III. PACKER LEVEL PRICES OF CATTLE AND HOGS

Theoretical Packer Level Price Equation

To meat packers, cattle and hogs represent essential inputs in the production of carcass beef and wholesale pork cuts. Thus, it is appropriate to apply the theory relevant to demand for productive inputs to the packer demand for slaughter cattle and hogs.

Given the assumption of profit maximization, a producer's demand for a productive resource is dependent upon the technical conditions of production, the prices of cooperating variable resources, the price of the firm's output, and the price of the resource itself[3] (Heady and Tweeten, 1963, p. 48).

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[3]The *level* of fixed resources influences the *level* of demand for variable resources. However, the level of fixed resources has no influence over variation in the levels of variable resources, thus fixed resources will implicitly enter the function by way of an intercept term.

In the meat packing industry an important variable resource cooperating with cattle and hogs is labor. Therefore, the price of labor in the meat packing industry becomes a variable in the packer demand functions for cattle and hogs.

In a manner analogous to producers' inventories of cattle and hogs, another factor which may be considered important by packers is their inventory of dressed beef and pork, in other words, cold storage of beef and pork (Myers, 1968). Packers can manipulate inventories of the two meats for reasons of convenience, speculation, and necessity; that is, to supply a buffer between the demands for wholesale meat and supply of cattle and hogs, to better take advantage of price changes in cattle, hogs, wholesale beef and pork, and for purposes of maintaining a smooth flow in plant operations.

Lastly, prices of outputs—the prices of wholesale beef and pork—are likely to be very important in explanation of variations in prices of cattle and hogs, respectively.

The theoretical demand function for cattle or hogs may be written

$$P^* = g(Q^{*d}, P_w^*, \Delta CS^*, W_p)$$

where

P^* = actual liveweight price,

Q^{*d} = liveweight quantity demanded,

P_w^* = wholesale price,

ΔCS^* = net first of month to end of month change in cold storage as defined in identities (e) and (f) of this chapter, and

W_p = wage rate in the packing industry.

All variables included in this theoretical equation have suitable empirical counterparts.

Statistical Packer Level Price Equations

To the theoretical equations was added variables to account for differing numbers of hours of operation of packing plants among months, intercept change dummy variables on months, variables to account for changes in the composition of slaughter cattle and hogs, and, in the demand for cattle equation, time trend.

The concept and calculating method for hours of packing plant operation were taken from the study by Hayenga and Hacklander (1970). Weekdays, holidays, and Saturdays in each month were weighted and summed to arrive at the number of utilized workdays per month (WD), utilizing the weights assumed in this earlier study.[4]

The statistical equation for demand for slaughter cattle is:

$$P_c^* = \beta_{0.3} + \gamma_{1.3}Q_c^{*d} + \gamma_{2.3}P_{wb}^* + \gamma_{3.3}\Delta CS_b^* + \beta_{1.3}W_p + \beta_{2.3}WD + \beta_{4.3}PC + (\beta_{4.3} \text{ through } \beta_{14.3})M + \beta_{15.3}T + e_3 \quad (3)$$

where

P_c^* = average liveweight price for slaughter steers, dollars per hundredweight, seven leading stockyards (U.S.D.A., 1971),

[4]These weights were: weekdays = 1, Saturdays = 1/3, weekday holidays = 1/2, Saturday holidays = 0, Sundays = 0 (Hayenga and Hacklander, 1970).

Q_c^{*d} = quantity of cattle demanded by packers, that is, $Q_c^{*d} = Q_c^{*s}$,

P_{wb}^{*} = weighted average of price quotations, cents per pound, on choice grade beef carcasses, four cities (U.S.D.A., 1971),

ΔCS_b^{*} = change in cold storage holdings of frozen and cured beef, millions of pounds, 48 states (U.S.D.A., 1971) as defined in identity (e) below,

W_p = average wage rate ($/hour) for employees in the meat packing industry (U. S. Department of Labor, 1964-1972),

WD = number of utilized workdays for meat packers,

PC = percentage of cattle slaughter consisting of cows (U.S.D.A., 1971), and

T and M are as previously defined.

The statistical equation for packer demand for slaughter hogs is:

$$P_h^{*} = \beta_{0.4} + \gamma_{1.4}Q_h^{*d} + \gamma_{2.4}P_{wp}^{*} + \gamma_{3.4}\Delta CS_p^{*} + \beta_{1.4}W_p + \beta_{2.4}WD + \beta_{3.4}PS + (\beta_{4.4} \text{ through } \beta_{14.4})M + e_4 \quad (4)$$

where

P_h^{*} = average liveweight price of barrows and gilts, dollars per hundredweight, eight leading stockyards (U.S.D.A., 1971),

Q_h^{*d} = quantity of hogs demanded by packers, that is, $Q_h^{*d} = Q_h^{*s}$,

P_{wp}^{*} = weighted average price, cents per pound, of wholesale pork cuts, Chicago basis (U.S.D.A., 1971),

ΔCS_p^{*} = change in cold storage holdings of frozen and cured pork, 48 states (U.S.D.A., 1971) as defined in identity (f) below, PS = percentage of hog slaughter consisting of sows (U.S.D.A., 1971), and

W_p, WD, and M are as previously defined.

As is usual in demand analysis, it is expected that as the quantity of the good in question (Q_c^{*d} or Q_h^{*d}) rises, the price of the good (P_c^* or P_h^*) must fall, ceteris paribus. Thus, it is expected that $\gamma_{1.3}$ and $\gamma_{1.4}$ will be negative.

As the price of output (P_{wb}^* or P_{wp}^*) rises, the respective prices of cattle and hogs (P_c^* or P_h^*) will be bid upward, ceteris paribus. It is therefore expected that $\gamma_{2.3}$ and $\gamma_{2.4}$ will be positive.

Cold storage is a stock variable and is thus measured at a point in time. That is, in order to represent such a variable across a time span such as a month, it is necessary to take into account beginning and ending stocks. The present study takes the view that an appropriate method of accomplishing this is to use net change measured from beginning of month to end of month.[5]

If packers believe that cold storage is at a level low relative to some desired level they would add to their stocks of meat in cold storage (ΔCS^* would be positive). In accomplishing this goal, that is by actively increasing the level of stocks, prices of market animals would

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[5] The method used in the present study is taken from the study by Hayenga and Hacklander (1970). Hayenga and Hacklander included beginning stocks of cold storage as a separate variable; however, the present study adopts the view that the impact of beginning stocks is primarily on change in cold storage (ΔCS^*) and not packer demand.

be bid up in the attempt to obtain an extra quantity. Thus it can be expected that $\gamma_{3.3}$ and $\gamma_{3.4}$ will be positive.

On the other hand, if the view is taken that cold storage represents a residual then a different result is obtained. That is, if an increase in inventory is viewed by packers as a sign to decrease current purchases of market animals then it would be expected that $\gamma_{3.3}$ and $\gamma_{3.4}$ are negative.

The view adopted is the former one. That is, it is hypothesized that packers bid prices up and down in order to achieve some desired level of cold storage inventories. The higher are packers' costs, as reflected by wage rates (W_p), the lower will be the price they are willing to pay for slaughter animals, <u>ceteris paribus</u>. It is thus expected that $\beta_{1.3}$ and $\beta_{1.4}$ will be negative.

With an increase in the number of workdays (WD) pressure is put on packers to increase the total quantity of meat processed, thus increasing the price of cattle and hogs (P_c^* and P_h^*), <u>ceteris paribus</u>. Therefore, it is expected that $\beta_{2.3}$ and $\beta_{2.4}$ be positive.

If there is an increase in the percentage of slaughter consisting of lower quality animals, higher quality animals will become relatively scarce and their price will be bid upwards, <u>ceteris paribus</u>. Thus, as the percentages of slaughter consisting of cows or sows rises the price of steers or market hogs should also rise if cows or sows are not considered perfect substitutes for steers or barrows and gilts by packers. It is therefore expected that $\beta_{3.3}$ and $\beta_{3.4}$ be positive.

During the period 1966-1970 there was a trend toward higher grades in cattle, with poundage of Prime and Choice carcasses increasing from 82.4 percent to 86.4 percent of total pounds slaughtered (U.S.D.A., 1971). It was felt that this trend would have resulted in an upward movement of composite slaughter cattle prices, *ceteris paribus*. A time trend variable (T) was added to the cattle demand equation in an attempt to account for this change. It is expected that the coefficient for this variable ($\beta_{15.3}$) be positive.

It is not thought that there has been a similar trend in the quality composition of market hogs over the seven year data span. Therefore, no time trend variable was included in the packer demand equation for hogs.

IV. CHANGES IN COLD STORAGE OF BEEF AND PORK

Theoretical Change in Cold Storage Equation

This study takes the view that meat packers, in a manner quite analogous to cattle and hog producers, change inventory levels in response to changes in other variables. In particular, it is postulated that packers, in deciding upon changes in cold storage, take into consideration present and expected prices, quantities of meat produced,[6] and the level of their stocks. The theoretical equation for change in cold storage may be expressed as:

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[6]See identities (c) and (d) below for definitions of production.

$$\Delta CS^{*} = h(P^{*e\Delta}, P_{w}^{*}, Q_{p}^{*}, CS_{(t-1)})$$

where

ΔCS^{*}, $P^{*e\Delta}$, and P_{w}^{*} are as previously defined,

Q_{p}^{*} = quantity produced, wholesale weight basis, and

$CS_{(t-1)}$ = beginning cold storage stocks.

Statistical Change in Cold Storage Equation

Dummy variables for months (M) were added in the statistical versions of the change in cold storage equation above to account for any effects of monthly patterns in marketings of slaughter animals on cold storage. It is expected that the coefficients of these dummy variables would be negative when production is at a seasonal low and positive when at a seasonal high, *ceteris paribus*.

The statistical equation for change in cold storage of beef is:

$$\Delta CS_{b}^{*} = \beta_{0.5} + \gamma_{1.5}P_{c}^{*e\Delta} + \gamma_{2.5}P_{wb}^{*} + \gamma_{3.5}Q_{pb}^{*} + \beta_{1.5}CS_{b(t-1)} + (\beta_{2.5} \text{ through } \beta_{12.5})M + e_{5} \quad (5)$$

where

ΔCS_{b}^{*}, $P_{c}^{*e\Delta}$, P_{wb}^{*}, and M are as previously defined,

Q_{pb}^{*} = commercial production of beef, millions of pounds, as defined by identity (c) below, and

$CS_{b(t-1)}$ = beginning (first of month) stocks of beef (U.S.D.A., 1971).[7]

[7]It is assumed that the stock of cold storage on hand at the beginning of a month equals the ending stock of the previous month.

The statistical equation for change in cold storage of pork is:

$$\Delta CS_p^* = \beta_{0.6} + \gamma_{1.6} P_h^{*e\Delta} + \gamma_{2.6} P_{wp}^* + \gamma_{3.6} Q_{pp}^* + \beta_{1.6} CS_{p(t-1)}$$
$$+ (\beta_{2.6} \text{ through } \beta_{12.6}) M + e_6 \qquad (6)$$

where

ΔCS_p^*, $P_h^{*e\Delta}$, P_{wp}^*, and M are as previously defined,

Q_{pp}^* = commercial production of pork as defined by identity (d) below, and

$CS_{p(t-1)}$ = beginning (first of month) cold storage stocks of pork (U.S.D.A., 1971).

If expected change in price of live animals ($P_c^{*e\Delta}$ or $P_h^{*e\Delta}$) is positive packers would increase cold storage stocks in order to reduce their buying of animals in the ensuing month, ceteris paribus. In other words, it is expected that $\gamma_{1.5}$ and $\gamma_{1.6}$ are positive.

If there is an increase in the current wholesale price of either meat (P_{wb}^* or P_{wp}^*), packers would be led to sell from cold storage, thus increasing their revenues, ceteris paribus. Therefore, change in cold storage would be negative given an increase in wholesale price, and it is expected that $\gamma_{2.5}$ and $\gamma_{2.6}$ will be negative.

With an increase in production (Q_{pb}^* or Q_{pp}^*) packers would feel pressure to increase their levels of cold storage, ceteris paribus. It is thus expected that $\gamma_{3.5}$ and $\gamma_{3.6}$ are positive.

Lastly, as the beginning inventory of cold storage ($CS_{b(t-1)}$ or $CS_{p(t-1)}$) increases, packers would feel pressure to reduce stocks, especially if cold storage facilities are limited. Therefore it is expected that $\beta_{1.5}$ and $\beta_{1.6}$ are negative, ceteris paribus.

V. WHOLESALE TO RETAIL MARKETING MARGINS FOR BEEF AND PORK

Theoretical Marketing Margin Equation

The connecting links between the prices received by meat packers for wholesale beef and pork and prices received by retailers are the wholesale to retail marketing margins for these meats.

It is assumed in this study that wholesale to retail marketing margins for both beef and pork respond to economic forces, rather than being oligopolistic in nature. Past studies which have attempted to deal with meat industry marketing margins on this basis have generally been inconclusive, particularly with respect to the effects of quantities marketed on margins (Breimyer, 1957; Buse and Brandow, 1960; Harlow, 1962; Myers, 1968). On the other hand, the studies cited do agree that quantity marketed, wholesale prices paid by marketing firms, and costs, as generally reflected by wage rates are three variables which are possibly important in explaining meat marketing margins.

The theoretical wholesale to retail marketing margin equation may be stated as:

$$M^* = i(C^*, P_w^*, W_r)$$

where

M^* = the wholesale to retail marketing margin,

C^* = consumption of meat as defined in identities (g) and (h) below,

W_r = wage rate for retail meat marketing firms, and

P_w is as previously defined.

Statistical Marketing Margin Equations

Of the variables which appear in the theoretical equation, only consumption of beef (C_b^*) has no appropriate published data source. However, given production and net change in cold storage of carcass beef and pork, the quantities of wholesale beef and pork moving to retail stores is known with a degree of certainty. These relationships for beef and pork are given explicitly by identities (i) and (j) of this chapter.

The statistical version of the margin equation for beef is:

$$M_b^* = \beta_{0.7} + \gamma_{1.7}C_b^* + \gamma_{2.7}P_{wb}^* + \beta_{1.7}W_r + e_7 \qquad (7)$$

where

M_b^* = wholesale to retail marketing margin for beef, that is, M_b^* equals retail price minus wholesale price, as defined by identity (g) of this chapter,

C_b^* = consumption of beef, as defined by identity (i) below,

W_r = wage rate (\$/hour) in retail food stores (U. S. Department of Labor, 1964-1972), and

P_{wb}^* is as previously defined.

The statistical version of the margin equation which applies to pork is:

$$M_p^* = \beta_{0.8} + \gamma_{1.8}C_p^* + \gamma_{2.8}P_{wp}^* + \beta_{1.8}W_r + e_8 \qquad (8)$$

where

M_p^* = wholesale to retail marketing margin for pork, that is, M_p^* equals retail price minus wholesale price as defined by identity (b) of this chapter,

C_p^* is as defined by identity (i) of this chapter, and P_{wp}^* and W_r are as previously defined.

Directions of influence of the quantities of beef or pork consumed, that is, the quantity passing through retail outlets (C_b^* or C_p^*), on margins are difficult to state, a priori. An increase in quantity marketed should be associated with wholesale and retail price decreases for both meats, ceteris paribus. If the wholesale prices fall more than respective retail prices, given the increase in consumption, then margins increase and $\gamma_{1.7}$ and $\gamma_{1.8}$ would be positive. However, if wholesale prices fall less than retail prices, then margins will narrow, given an increase in consumption, and $\gamma_{1.7}$ and $\gamma_{1.8}$ would be negative. In other words, the signs of $\gamma_{1.7}$ and $\gamma_{1.8}$ depend upon the relative responsiveness of retail and wholesale prices to changes in quantities marketed.

It is equally difficult to state, a priori, the direction of influence of wholesale prices on margins. A positive coefficient for this variable would indicate that retailers are able to increase their margins given a rise in wholesale price, a zero coefficient would indicate that retail and wholesale price rise and fall together by equal dollar amounts, and a negative coefficient would be indicative of retailers accepting smaller margins when wholesale price rises.

As the wage rate paid by retail marketing firms (W_r) increases, pressure will be put on these firms to increase margins in order to meet increased costs, ceteris paribus. Thus, it is expected that $\beta_{1.7}$ and $\beta_{1.8}$ are positive.

VI. RETAIL DEMAND FOR BEEF, PORK AND BROILERS

Theoretical Retail Demand Equations

The theory of consumer demand is well developed and can be readily applied to the retail demand for meats. In general, there are five classes of variables which affect consumer demand: (a) the price of the good itself, (b) prices (or quantities) of goods which substitute for or are complements to the good, (c) income, (d) tastes and preferences, and (e) the size of the consuming population.

For the purposes of this study the only substitutes to be considered for beef and pork and broilers will be the remaining two, once the quantity variable is defined in terms of one of the three meats. Tastes and preferences, insofar as they are influenced by time of the year, will be measured indirectly by the use of (0,1) intercept dummy variables for months.

The retail demand function for beef and pork is:

$$C^* = j(P_r^*, P_{rs}^*, I, P, M)$$

and, for reasons given below, the retail demand function for broilers is:

$$P_r^* = k(C_{br}, P_{rs}^*, I, P, M)$$

where

C^* is as previously defined,

P_r^* = the retail price of the meat,

P_{rs}^* = the retail price of the substitute meats,

I = income,

P = population,

M is as previously defined, and

C_{br} = consumption of broilers.

Statistical Retail Demand Equations

During the period covered by this study, monthly personal income and population were highly correlated (r = 0.993).[8] Therefore, in order to obtain meaningful estimated coefficients for income, population was removed as a separate variable by placing consumption and income on a per capita basis.

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[8]A high degree of correlation between two variables in general, reduces the reliability of the estimated coefficients for both (Wonnacott and Wonnacott, 1970).

The statistical retail demand function for beef is:

$$C_b^{*pc} = \beta_{0.9} + \gamma_{1.9}P^*_{rb} + \gamma_{2.9}P^*_{rp} + \gamma_{3.9}P^*_{rbr} + \beta_{1.9}I^{pc}$$
$$+ (\beta_{2.9} \text{ through } \beta_{12.9})M + e_9 \qquad (9)$$

where

C_b^{*pc} = per capita consumption of beef, that is, $C_b^{*pc} = C_b^*/p$, where C_b^* is as previously defined and P = U. S. population (millions of persons) (U. S. Department of Commerce, 1964-1971),

P^*_{rb} = retail price of beef, cents per pound, weighted average, as reported by a group of food chains and Bureau of Labor Statistics (U.S.D.A., 1971),

P^*_{rp} = retail price of pork, cents per pound, weighted average, as reported jointly by a group of food chains and Bureau of Labor Statistics (U.S.D.A., 1971),

P^*_{rbr} = retail price of broilers, cents per pound, 50 urban areas (U.S.D.A., 1970; U.S.D.A., 1969-1972),

I^{pc} = per capita monthly U. S. personal income in current dollars, that is, $I^{pc} = I/p$ where I is U. S. personal income and P is U. S. population (U. S. Department of Commerce, 1964-1971), and

M is as previously defined.

The retail demand function for pork is directly analogous to that for beef. The statistical equation is:

$$C_p^{*pc} = \beta_{0.10} + \gamma_{1.10}P^*_{rp} + \gamma_{2.10}P^*_{rb} + \gamma_{3.10}P^*_{rbr} + \beta_{1.10}I^{pc}$$

$$+ (\beta_{2.10} \text{ through } \beta_{12.10})M + e_{10} \quad (10)$$

where

C_p^{*pc} = per capita consumption of pork, that is, $C_p^{*pc} = C_p^*/p$, where C_p^* and P are as previously defined, and

P^*_{rp}, P^*_{rb}, P^*_{rbr}, I^{pc}, and M are as previously defined.

As the retail prices of beef or pork (P^*_{rb} or P^*_{rp}) increase in their respective retail demand equations, that is, equations (9) or (10), consumers would demand less beef or pork, ceteris paribus. Therefore, it is expected that $\gamma_{1.9}$ and $\gamma_{1.10}$ are negative.

When one good substitutes for another, a rise in the price of one good will lead consumers to purchase more of the now relatively less expensive good, ceteris paribus. Therefore, positive signs for the coefficients of prices of substitute meats in equations (9) and (10), that is, $\gamma_{2.9}$, $\gamma_{3.9}$, $\gamma_{2.10}$, and $\gamma_{3.10}$, are to be expected if beef, pork, and broilers are mutual substitutes.

If beef and pork are normal goods a priori an increase in income (I^{pc}) would lead to an increase in demand, ceteris paribus. It is expected that both $\beta_{1.9}$ and $\beta_{1.10}$ are positive.

Poultry, and in particular broilers, may be an important substitute for beef and pork at the retail level. Any model of the beef and pork sector which attempts to analyze the retail marketing level should take this interaction into consideration. There is, however, a characteristic of broiler production which enables a much simpler representation of the broiler marketing system, than was the case for beef and pork.

Unlike cattle and hog producers, producers of broilers do not have the option of holding market livestock in inventory for any appreciable period of time. A broiler chick becomes a mature, market-ready bird in a time span of only about seven to eight weeks, and after that deteriorates in quality rather quickly. Thus, it is not unreasonable to assume that the quantity of broilers coming onto the market may be taken as predetermined within a period as short as a month. With quantity produced predetermined it is assumed that farm level and wholesale prices, cold storage and consumption are also predetermined. Retail price of broilers is, on the other hand, endogenous to the model as it interacts with endogenous price variables in the beef and pork sectors. That is, the rationale is for making price (as opposed to consumption) left hand side variable in this equation.

The retail demand for broilers is therefore:

$$P^*_{rbr} = \beta_{0.11} + \beta_{1.11}C^{pc}_{br} + \gamma_{1.11}P^*_{rb} + \gamma_{2.11}P^*_{rp} + \beta_{2.11}I^{pc} + (\beta_{3.11} \text{ through } \beta_{13.11})M + e_{11} \quad (11)$$

where

C^{pc}_{br} = per capita consumption of broilers, that is, $C^{pc}_{br} = C_{br}/P$, where C_{br} is defined by identity (k) of this chapter and P is as previously defined, and

P^*_{rbr}, P^*_{rb}, P^*_{rp}, I^{pc}, and M are as previously defined.

It is usually expected that in demand analysis an inverse relationship exists between the price and quantity of the good in question, ceteris paribus. Thus, it is expected that $\beta_{1.11}$ is negative. An increase in the price of a substitute (P^*_{rb} or P^*_{rp}) for a good leads to an increase in the demand for the good in question, thus a price rise for the good in question, ceteris paribus. Therefore, it is expected that $\gamma_{1.11}$ and $\gamma_{2.11}$ are positive.

There is no strong reason to believe that broilers, like beef and pork, are a normal good. Although there has in the recent past been a substantial increase in broiler consumption, this could have come from shifts in the broiler supply function rather than increases in income.

VII. EXPECTED CHANGE IN PRICE OF CATTLE AND HOGS IDENTITIES

Equations which define the expected change in prices of cattle and hogs are not in themselves central to the model. No attempt will be made to develop an innovative price expectation model. Rather, a simple but nonetheless plausible model defining this unobservable variable is postulated. To begin with, expected price is defined as:

$$P^{*e} = \delta_0 + \delta_1 P^* + \delta_2 P_{(t-1)} + \delta_3 P_{(t-2)}$$

where

P^{*e} = expected price,

P^* is as previously defined, and $P_{(t-1)}$ and $P_{(t-2)}$ are P^* lagged one and two periods respectively.

It is thus assumed that in forming short term expected price for cattle or hogs producers of cattle or hogs and holders of beef or pork cold storage project current and near past price levels into the near future. This assumption may not be too unrealistic, given the highly autoregressive nature of prices in these markets.

Application of the expectation model to cattle and hog prices yields the equations below,

$$P_c^{*e} = \delta_{0.a} + \delta_{1.a}P_c^{*} + \delta_{2.a}P_{c(t-1)} + \delta_{3.a}P_{c(t-2)}$$

$$P_h^{*e} = \delta_{0.b} + \delta_{1.b}P_h^{*} + \delta_{2.b}P_{h(t-1)} + \delta_{3.b}P_{h(t-2)}$$

In order to determine weights to be used in defining P_c^{*e} and P_h^{*e} the above two identities were allowed to become stochastic equations with associated error terms. The dependent variables of these equations were price of cattle and price of hogs in month t+1, respectively. Ordinary least squares[9] was applied and a set of weights were estimated.

The identities which resulted from this procedure are:

$$P_c^{*e} \equiv 1.9306 + 1.2875P_c^{*} - 0.5034P_{c(t-1)} + 0.1456P_{c(t-2)} \qquad (a')$$

$$P_h^{*e} \equiv 2.0424 + 1.3405P_h^{*} - 0.4854P_{h(t-1)} + 0.0478P_{h(t-2)} \qquad (b')$$

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[9]It is recognized that the estimated weights, the δ's, are statistically biased due to the use of ordinary least squares with variables known to be endogenous present on the right hand sides of the two equations. However, in small samples OLS may give more accurate predictions than two stage least squares and for this reason was chosen to estimate the δ's.

where all variables are as previously defined.[10]

Expected change in price is then the difference between expected price, as calculated from the weighted summation, and respective actual liveweight price, that is, (a) and (b) below.

$$P_c^{*e\Delta} \equiv P_c^{*e} - P_c^{*} \qquad \text{(a)}$$

where

$P_c^{*e\Delta}$ = expected change in liveweight price of cattle, and

P_c^{*e} and P_c^{*} are as previously defined.

$$P_h^{*e\Delta} \equiv P_h^{*e} - P_h^{*} \qquad \text{(b)}$$

where

$P_h^{*e\Delta}$ = expected change in liveweight price of hogs, and

P_h^{*e} and P_h^{*} are as previously defined.

VIII. BEEF AND PORK PRODUCTION IDENTITIES

Production of wholesale beef and pork (Q_{pb}^{*} and Q_{pp}^{*}) differs from liveweight slaughter of cattle and hogs (Q_c^{*s} and Q_h^{*s}) by only a constant

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[10]For equation (a´) the coefficient of determination (R^2) equaled 0.90 and the standard error of estimate (S) equaled \$0.87 per hundredweight. For equation (b´) R^2 was 0.89 and S was \$1.28 per hundredweight.

dressing proportion.[11] Therefore, it is possible to define production of the two meats at the wholesale level in terms of nonstochastic equations, that is, identities (c) and (d) below.

$$Q^{*}_{pb} \equiv Q^{*s}_{c} \times DP_{c} \tag{c}$$

where

Q^{*}_{pb} and Q^{*s}_{c} are as previously defined, and

DP_{c} = the dressing proportion for cattle, that is, 0.584 (U.S.D.A., 1971).

$$Q^{*}_{pp} \equiv Q^{*s}_{h} \times DP_{h} \tag{d}$$

where

Q^{*}_{pp} and Q^{*s}_{h} are as previously defined, and

DP_{h} = the dressing proportion for hogs, that is, 0.703 (U.S.D.A., 1971).

It is thus assumed that the dressing proportions (DP_{c} and DP_{h}) are parameters of the system and not variables.

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[11]Actually, this proportion does vary somewhat over time. However, the variation is so slight as to make the first stage estimates of the two stage least squares estimating technique quite sensitive to small changes in the proportions, if they are included as predetermined variables. As the stability of the forecast values of the first stage equations will become quite important at a later point it was assumed that the dressing proportions were constant at their respective means.

IX. CHANGE IN COLD STORAGE OF BEEF AND PORK IDENTITIES

The identities for change in cold storage of beef and pork were given implicit mention in behavioral equations (3) and (4) above. Explicitly, these identities appear as (e) and (f) below.

$$\Delta CS_b^* \equiv CS_b^* - CS_{b(t-1)} \qquad \text{(e)}$$

where

ΔCS_b^* and $CS_{b(t-1)}$ are as previously defined, and

CS_b^* = end of month inventory of beef, cold storage (U.S.D.A., 1971).

$$\Delta CS_p^* \equiv CS_p^* - CS_{p(t-1)} \qquad \text{(f)}$$

where

ΔCS_p^* and $CS_{p(t-1)}$ are as previously defined, and

CS_p^* = end of month inventory of pork, cold storage (U.S.D.A., 1971).

X. WHOLESALE TO RETAIL MARKETING MARGIN IDENTITIES FOR BEEF AND PORK

These identities were implicitly mentioned in connection with the behavioral equations for the two marketing margins, equations (7) and (8). They are shown explicitly as identities (g) and (h) below.

$$M_b^* = P_{rb}^{*w} - P_{wb}^* \tag{g}$$

where

M_b^* and P_{wb}^* are as previously defined, and

P_{rb}^{*w} = retail price of beef, as defined in equation (9) of this chapter, but on a wholesale weight basis, that is, $P_{rb}^{*w} = P_{rb}^* \times DP_b$, where DP_b = the proportion of wholesale beef sold at retail as estimated by U.S.D.A., that is, 0.709 (U.S.D.A., 1971).

$$M_p^* = P_{rp}^{*w} - P_{wp}^* \tag{h}$$

where

M_p^* and P_{wp}^* are as previously defined, and

P_{rp}^{*w} = retail price of pork as defined in equation (9) of this chapter, but on a wholesale weight basis, that is, $P_{rp}^{*w} = P_{rp}^* \times DP_p$, where DP_p = the proportion of wholesale pork sold at retail as estimated by U.S.D.A., that is, 0.934 (U.S.D.A., 1971).

The adjustments made to retail prices merely reflect the fact that not all the wholesale carcass is sold as retail cuts. Equivalently, wholesale prices could have placed on a retail weight basis by multiplying them by the inverses of the respective dressing percentage.

XI. BEEF AND PORK CONSUMPTION IDENTITIES

Consumption of beef or pork (C_b^* or C_p^*) is defined as production of beef or pork minus respective change in cold storage times the respective proportions of wholesale beef and pork sold at retail. It is assumed that the primary form of beef cold storage is carcass beef and that of pork cold storage is wholesale cuts.

Although a considerable amount of beef is imported into the United States, very little of this finds its way to the retail meat counter. Since the present study concentrates on the retail market beef imports were omitted from the consumption calculations entirely.

The two identities are as (i) and (j) below.

$$C_b^* \equiv (Q_{pb}^* - \Delta CS_b^*) \times DP_b \qquad \text{(i)}$$

where C_b^*, Q_{pb}^*, ΔCS_b^*, and DP_b are as previously defined.

$$C_p^* \equiv (Q_{pp}^* - \Delta CS_p^*) \times DP_p \qquad \text{(j)}$$

where C_p^*, Q_{pp}^*, ΔCS_p^*, and DP_p are as previously defined.

XII. DERIVATION OF BROILER CONSUMPTION

Consumption of broilers is defined in a manner analogous to consumption of beef and pork.

There are three differences in this equation when compared to the definitions of beef and pork consumption. First, it was decided to include exports of broilers as a net reduction to domestic consumption, as exports of this item have risen and fallen rather rapidly in the recent past. Also, since all broiler production is sold at retail (neglecting spoilage and shipping losses), it is not necessary to include a wholesale to retail dressing proportion. Lastly, monthly broiler production, and thus consumption, was assumed to be predetermined. Thus, this equation is conceptually different from previous equations in that as there are no endogenous variables present, it is not an integral part of the model itself.

The identity defining consumption of broilers is as (k) below.

$$C_{br} \equiv Q_{pbr} + \Delta CS_{br} - EX_{br} \qquad \text{(k)}$$

where

C_{br} is as previously defined,

Q_{pbr} = production of lightweight chicken, dressed weight, millions of pounds (U.S.D.A., 1970; U.S.D.A., 1969-1972),

ΔCS_{br} = net change in cold storage of iced broilers, millions of pounds (U.S.D.A., 1970; U.S.D.A., 1969-1972), and

EX_{br} = exports of broilers, millions of pounds (U.S.D.A., 1970; U.S.D.A., 1969-1972).

XIII. MARKET CLEARING IDENTITIES

The condition of equality between amount demanded and amount supplied of cattle and hogs is made explicit by the two identities below.

$$Q_c^{*d} \equiv Q_c^{*s} \tag{l}$$

and

$$Q_h^{*d} \equiv Q_h^{*s} \tag{m}$$

where all variables are as previously defined.

XIV. PRICE DEFLATORS

When a model contains time series data on prices and/or income, it is usually desirable to correct for changes in these variables caused solely by changes in overall price levels. This is most commonly done by dividing (deflating) these variables by price indexes which reflect such price changes.

For this study retail prices, retail wages, and personal income were deflated utilizing the Consumer Price Index (CPI) (U. S. Department of Commerce, 1964-1971). Wholesale prices, packer level prices, and packer wage rates were similarly treated utilizing the Wholesale Price Index (WPI) (U. S. Department of Commerce, 1964-1971). The following table (Table I) shows relationships among income and price variables in the model and their respective deflators. It was decided that two deflators would be used to reflect the fact that wholesale level and retail level prices may change at different rates. For some variables, retail wage rates for instance, choice of the appropriate deflator is arbitrary due to the fact that retailers and wholesalers are concerned with prices at more than one marketing level.

TABLE I

PRICE DEFLATORS USED AND VARIABLES TREATED

Deflator[a]	Variables Treated
CPI (1957-1959 = 100)	P^*_{rb}, P^*_{rp}, P^*_{rbr}, W_r, I^{pc}
WPI (1957-1959 = 100)	P^*_c, $P^{*e\Delta}_c$, P^*_h, $P^{*e\Delta}_h$, P^*_f, P^*_{wb}, P^*_{wp}, $P_{c(t-1)}$, $P_{c(t-2)}$, $P_{h(t-1)}$, $P_{h(t-2)}$, W_p, M^*_b, M^*_p

[a]U. S. Department of Commerce, Survey of Current Business, Washington, D.C., 1964-1971.

XV. METHOD OF STATISTICAL ESTIMATION

The statistical model presented in this chapter is an overidentified[12] set of simultaneous stochastic equations which represents the essential

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[12]For a discussion of the identification problem, see Wonnacott and Wonnacott (1970). Essentially, the problem concerns whether or not there is sufficient or more than sufficient information to mathematically determine a system's parameters. Each equation of this model (and therefore the entire model) is overidentified by the order criteria.

features of the United States beef-pork economy. There are several methods available for obtaining estimates of the parameters of this system.

Two general classes of techniques exist—single equation methods and multiequation methods. Multiequation methods were eliminated from consideration on the basis of the large sample size required for their use. From among the class of single equation methods two stage least squares (TSLS)[13] was chosen for use in this study. Some of the reasons for this were:

1. TSLS provides consistent[14] estimates of the parameters of a simultaneous system.
2. TSLS performs relatively well as compared to alternate methods under conditions of multicollineality among the exogenous variables and specification errors (Wonnacott and Wonnacott, 1970).
3. In terms of computational ease and efficiency, TSLS ranks highest among consistent single equation methods (Wonnacott and Wonnacott, 1970).

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[13]See Goldberger (1964) or Wonnacott and Wonnacott (1970) for a detailed description of this and other methods.

[14]Consistent in the sense that as the sample size approaches infinity, the parameter estimates approach true parameter values.

CHAPTER III

STATISTICAL RESULTS AND TEST OF THE MODEL

I. EVALUATION CRITERIA FOR ESTIMATED STRUCTURAL EQUATIONS

Within this chapter are presented the results of applying two stage least squares to the data set defined by the statistical equations previously developed. Also presented is an analysis of the postsample period structure of the beef-pork industry. Here, actual values for the exogenous variables in the model are used to calculate values for the endogenous variables. These calculated values are then compared to actual values for the endogenous variables to determine if the sample period structure tracks the actual values of the endogenous variables.

Individual Structural Parameter Estimates

Individual structural coefficients, as estimated by TSLS, will be evaluated on the basis of conformity to their respective *a priori* signs and, also, their size relative to respective estimated standard errors.[1] Two conventions will be observed with respect to the latter of the two evaluations. If a given coefficient is at least as large as its standard

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[1] It is known that the standard errors of structural coefficients as estimated by TSLS are statistically biased (Christ, 1966, p. 441), and as such they are sometimes referred to as asymptotic standard errors. For this study the term standard error is equivalent to the term asymtotic standard error in the context of structural parameters.

error it will be termed "economically significant" and its standard error will be denoted by a superscript "*". A coefficient which is at least twice as large as its standard error will be called "statistically significant" and its standard error will be denoted by a superscript "**".[2]

For intercept change dummy variables "significance" is interpreted with respect to an excluded class. Therefore, significance levels for individual dummy variables on months used in this study must be interpreted to mean significance from January, the excluded month. Thus, levels of significance for these variables are arbitrary in the sense that the month selected for exclusion is arbitrary.

With respect to the exact implications of the estimated structural parameters there may be, in one respect, a degree of ambiguity. The difficulty arises from the postulated simultaneous relationship. That is, it may be somewhat unrealistic in a structural equation to speak of the effect on the normalized variable of a small change in another variable, all else held constant. To say that the exact marginal effect of a small change in a right hand side variable is the variables' structural coefficient may, in a sense, deny the basic idea of a simultaneous system, that is, a system in which values taken by one endogenous variable

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[2]As the small sample properties of TSLS estimates are not known precisely any division made between a significant coefficient and an insignificant coefficient is necessarily arbitrary in nature. In ordinary least squares coefficients may be tested utilizing the t distribution which rejects at $\alpha = .05$ the null hypothesis that a coefficient equals zero if its standard error is about twice the absolute magnitude of the coefficient.

influences concurrent values of all other endogenous variables. The principal implication of this is in the calculation of elasticities, where marginal effects are a necessary part of the computations.

It is obvious from the above discussion that it is possible to say that the exact marginal effect of a change in a variable on the normalized variable is not available from the structural parameters. However, the present study takes the view that elasticities computed from the structural coefficients may be taken as approximations which do give considerable insight into relative responsiveness of quantities to change in other variables.

Lastly, as deflated prices, wages and income were used in estimating the model, all coefficients for such variables must be interpreted with this in mind. Where specific levels are mentioned for these variables they refer to values deflated with the price indexes shown in Table I, page 46.

Goodness of Fit of Structural Equations

In evaluating the degree to which the right hand side variables in a structural equation explain variations in the left hand side variable it is tempting to use a statistic analogous to R^2 in ordinary least squares. However, Basmann (1962) points out that whereas R^2 must lie between 0 and 1 the value computed for this statistic in the context of a structural equation of a simultaneous system can be negative.

However, in the context of two stage least squares a statistic can be defined which gives an estimate of the variance of the structural disturbance term (Christ, 1966). This is defined by:

$$\hat{\sigma}_e^2 = \frac{1}{T - H - J + 1} \sum_{t=1}^{T} \hat{e}_t^2$$

where

$\hat{\sigma}_e^2$ = estimated variance of e,

T = total numbers of observations,

H = number of included endogenous variables,

J = number of included predetermined variables, and

$\hat{e}_t^2$ = square of the $t^{\underline{th}}$ estimated error term for a given structural equation.

This statistic measures the dispersion of the data points around the fitted regression surface. In general, about 95 percent of the observations on the left hand side variable will lie between $\pm 2\hat{\sigma}_e$.

The square root of this statistic ($\hat{\sigma}_e$) will be reported following each structural equation.

II. STATISTICAL RESULTS

Quantity of Cattle Marketed by Farmers

The TSLS estimates for this equation (where the numbers in parentheses denote TSLS standard errors) are:

$$\hat{Q}_c^{*s} = \underset{(488.730)^{**}}{1983.670} - \underset{(49.756)^{*}}{57.246}\, P_c^{*e\Delta} + \underset{(53.474)^{*}}{79.771}\, I_c$$

$$- \underset{(24.305)^{*}}{45.128}\, S2 - \underset{(24.636)^{*}}{38.632}\, S3 + \underset{(265.761)}{126.864}\, FEB$$

$$+ \underset{(269.731)}{225.110}\,MAR - \underset{(70.945)^{**}}{184.964}\,APR + \underset{(261.387)^{*}}{352.002}\,MAY$$

$$+ \underset{(263.283)^{*}}{320.538}\,JUN + \underset{(128.422)}{12.655}\,JUL + \underset{(269.030)^{*}}{467.655}\,AUG$$

$$+ \underset{(267.832)^{*}}{468.457}\,SEP + \underset{(143.456)^{*}}{245.872}\,OCT + \underset{(274.148)^{*}}{367.832}\,NOV$$

$$+ \underset{(272.819)^{*}}{385.827}\,DEC - \underset{(141.406)}{13.055}\,P_f + \underset{(2.572)^{*}}{3.678}\,T \qquad (1)$$

$$\hat{\sigma}_e = 106.11 \text{ (millions of pounds)}$$

Coefficients for expected change in the price of cattle and price of feed in this equation are not statistically significant. It would seem then that prices are not critically important variables included in this equation.

To test this proposition quantity of cattle marketed was regressed on the predetermined inventory, time trend and intercept change variables of equation (1). Since OLS could be used to estimate this equation the value of R^2 has meaning, and therefore is reported.

The OLS equation is:

$$\hat{Q}_c^{*s} = \underset{(457.472)^{**}}{2145.923} + \underset{(50.260)^{*}}{62.912}\,I_c - \underset{(24.144)^{*}}{44.830}\,S2$$

$$- \underset{(24.144)^{*}}{43.701}\,S3 + \underset{(263.935)}{119.190}\,FEB + \underset{(263.967)^{*}}{283.057}\,MAR$$

$$- \underset{(68.064)^{**}}{204.120}\,APR + \underset{(259.624)^{*}}{331.770}\,MAY + \underset{(259.987)^{*}}{355.768}\,JUN$$

$$- \underset{(119.412)}{31.830}\,JUL + \underset{(264.258)^{*}}{419.183}\,AUG + \underset{(265.183)^{*}}{448.683}\,SEP$$

$$+ \underset{(133.796)^{*}}{191.906}\,OCT + \underset{(269.059)^{*}}{314.451}\,NOV + \underset{(270.106)^{*}}{387.875}\,DEC$$

$$+ \underset{(2.354)^*}{4.078\ T} \qquad (1a)$$

$$\hat{\sigma}_e = 105.68 \text{ (millions of pounds)}$$

$$R^2 = 0.779$$

Equation (1a) has a slightly smaller value for $\hat{\sigma}_e$, indicating that it fits the data somewhat "tighter" than did equation (1). All the decrease is accounted for by the change in the denominator of the statistic, that is, T-H-J+1 was increased by 2 in the inventory alone equation versus the equation with prices included, with the numerators being very nearly equal. The fact is that price of cattle, when formulated in the manner of this study, contributes little to the explanation of monthly cattle slaughter and thus leaves open the question of the appropriateness of either a simultaneous relation between cattle price and monthly supply of cattle for slaughter or the form of the price variable.

Slope coefficients for cattle inventory in equation (1) are interpreted as the effect of a change in cattle on feed on market quantity of slaughter cattle. To arrive at the slope coefficient for the second or third months of a quarter it is necessary to add the coefficient of S2 or S3 to the coefficient of I_c. Thus, a 1 unit (1 million) change in cattle on feed would result in 79.771, 34.643, and 41.139 million pound increases in slaughter of cattle during the first, second, and third months following a quarterly report, respectively.

A straightforward interpretation of the estimated monthly intercept dummy variables for equation (1) is somewhat difficult due to the presence of these slope changes among months. That is, when a straight line rotates through a point, as this equation does with respect to inventory of cattle among the three months of a quarter, a change in the intercept of that function is expected from this factor alone. Thus, the estimated monthly dummies measure two types of variation in quantity of cattle marketed: (1) a month to month variation in intercept, plus (2) the covariance between the slope change dummies on inventory and the overall equation intercept.

The component of the intercept dummies which is due to the covariance can, however, be calculated and used to adjust the estimated monthly intercept changes.

This was accomplished by assuming I_c at its mean,[3] a point through which the regression plane must pass, and multiplying this figure by the change in slopes for the second and third months of a quarter, that is, S2 and S3, respectively. The resulting numbers represent changes in the intercept due to the slope changes alone. Thus for example the estimated intercept change for February of 126.864 can be decomposed into two components, one, -431.644 = (9.563 × 45.128) representing an intercept change due to the change in slope with respect to I_c and two, -303.780 = (126.864 - 431.644) representing a change in intercept net of any change in slope. It is thought that these net intercept changes

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[3] Means, standard deviations, and ranges for all variables included in this study are reported in Tables 16 and 17 in the Appendix.

approximate values which would have been directly estimated for intercept dummy variables had monthly rather than quarterly cattle inventory numbers been used.

Adjusted monthly intercept values for equation (1) are shown graphically in Figure 1. Values taken by the adjusted intercepts as shown on this graph are not precisely those calculated by the procedure outlined above. The figures which resulted from separating slope change effects from pure intercept changes were adjusted such that their arithmetic mean equals the arithmetic mean of the dependent variable, quantity of cattle marketed. This in no way alters the pattern of the intercepts but does give a reference point from which to compare their magnitude. Similar adjustments were made to the graphical intercept patterns of all subsequent equations which include monthly intercept changes. Given effects of the other variables which affect cattle marketings, the adjusted intercept of equation (1) reaches a low in February, climbs steadily until October, then generally falls through February.

There are several reasons why this equation might be expected to show monthly variations in intercept values. A dominant factor here is thought to be the empirical definition of inventory as cattle on feed in twenty-three states. This variable thus excludes several components of total cattle slaughter, in particular range fed, dairy, and breeding cattle. It is felt that the monthly dummies, corrected for slope changes, reflect regular variations in the quantity of these classes of cattle coming into market channels. Lastly, if imports of live cattle were large in relation to the overall market and were not uniform in level

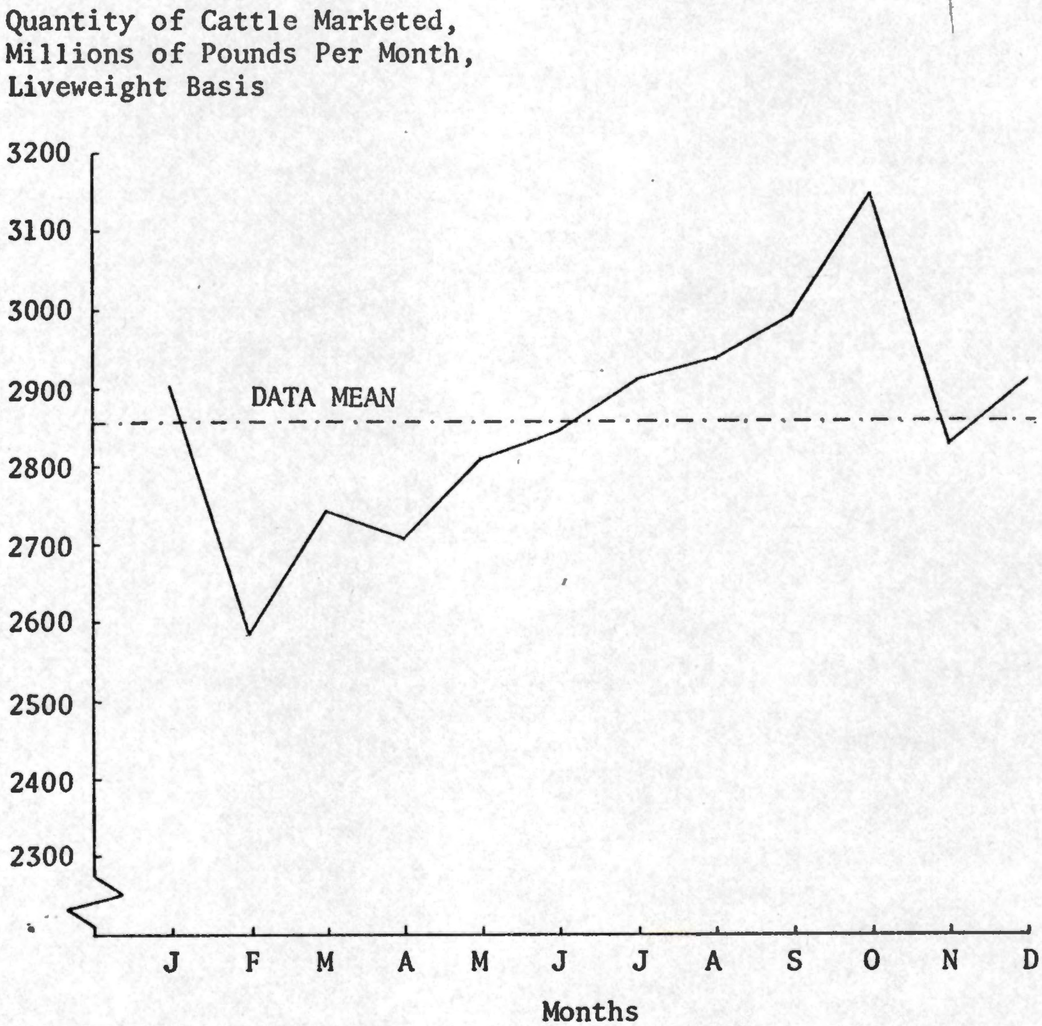

Figure 1. Adjusted monthly intercept values for equation (1).

throughout the year the monthly dummies would also measure variation from this source.

In general it can be stated that equation (1) shows cattle marketings varying directly with inventory of cattle on feed and time trend, and inversely with expected change in the price of cattle and current price of corn. The importance of the two price variables is open to serious question, based on a criteria of comparative standard errors of estimate between the two equations.

It was a stated objective of this study to evaluate the usefulness of cattle inventory numbers in predicting monthly variations in marketing of slaughter cattle. This objective will be more fully examined in the section of this chapter devoted to testing the structure of the model. There, calculated values for quantity of cattle slaughtered computed from equation (1a) will be compared with those from the reduced form equation for quantity of cattle marketed.

Quantity of Hogs Marketed by Farmers

The estimated equation for quantity of hogs marketed is:

$$\hat{Q}_h^{*s} = \underset{(402.794)^*}{-539.820} - \underset{(32.990)^*}{60.979}\, P_h^{*e\Delta} + \underset{(66.534)}{65.604}\, I_{h,60-119}$$

$$- \underset{(106.230)^*}{135.006}\, I_{h,120-179} + \underset{(124.043)^{**}}{311.636}\, I_{h,180-219}$$

$$- \underset{(91.173)}{62.720}\, S2_{60-119} + \underset{(148.003)^*}{205.635}\, S2_{120-179}$$

$$- \underset{(168.939)}{18.385}\, S2_{180-219} + \underset{(87.884)}{16.418}\, S3_{60-119}$$

$$+ \underset{(143.612)^{**}}{320.815}\ S3_{120-179} - \underset{(167.560)^{**}}{486.145}\ S3_{180-219}$$

$$+ \underset{(473.072)}{388.624}\ FEB + \underset{(465.734)^{**}}{1251.627}\ MAR + \underset{(218.664)}{115.042}\ APR$$

$$+ \underset{(456.962)^{*}}{565.643}\ MAY + \underset{(426.159)^{**}}{942.770}\ JUN + \underset{(159.014)^{**}}{381.950}\ JUL$$

$$+ \underset{(451.578)^{*}}{573.134}\ AUG + \underset{(473.316)^{**}}{963.877}\ SEP - \underset{(131.022)}{29.767}\ OCT$$

$$+ \underset{(483.621)}{335.078}\ NOV + \underset{(447.589)^{*}}{890.277}\ DEC + \underset{(111.692)}{100.556}\ P_f$$

$$+ \underset{(0.662)^{**}}{2.694}\ T \qquad (2)$$

$$\hat{\sigma}_e = 80.956 \text{ (millions of pounds)}$$

All estimated coefficients agree with a priori expectations with respect to sign.

As was the case for equation (1), supply of slaughter cattle, the price variables included in this equation are not statistically significant. Again, to ascertain the importance of price in the determination of quantity of hogs marketed $P_h^{*e\Delta}$ and P_f were eliminated and an OLS estimate was obtained for the remaining parameters.

The resulting estimated equation is:

$$\hat{Q}_h^{*s} = - \underset{(334.234)^{**}}{709.210} + \underset{(62.875)}{42.820}\ I_{h,60-119}$$

$$- \underset{(102.807)}{95.656}\ I_{h,120-179} + \underset{(121.396)^{**}}{370.985}\ I_{h,180-219}$$

$$- \underset{(88.087)}{19.327}\ S2_{60-119} + \underset{(141.556)}{123.940}\ S2_{120-179}$$

$$+ \underset{(169.383)}{15.403}\ S2_{180-219} + \underset{(88.087)}{33.545}\ S3_{60-119}$$

$$+ \underset{(141.557)^{*}}{266.029}\ S3_{120-179} - \underset{(169.383)^{**}}{468.322}\ S3_{180-219}$$

$$+ \underset{(471.946)^{*}}{524.040}\ FEB + \underset{(469.060)^{**}}{1143.487}\ MAR$$

$$+ \underset{(216.647)}{206.251}\ APR + \underset{(452.942)^{*}}{748.665}\ MAY$$

$$+ \underset{(409.286)}{1105.609}\ JUN + \underset{(144.001)^{**}}{490.063}\ JUL$$

$$+ \underset{(436.824)^{*}}{784.735}\ AUG + \underset{(475.333)^{*}}{838.358}\ SEP$$

$$- \underset{(132.736)}{17.000}\ OCT + \underset{(483.359)}{470.047}\ NOV$$

$$+ \underset{(449.607)^{*}}{882.137}\ DEC + \underset{(0.411)^{**}}{1.713}\ T \qquad (2a)$$

$\hat{\sigma}_e = 82.130$ (millions of pounds)

$R^2 = 0.862$

As was the case for marketings of cattle, based on comparative standard errors marketings of hogs are explained nearly as well by an OLS equation using only inventory and time trend as compared to a TSLS equation containing both inventory and price variables. Again, this may cast serious doubt upon the practical necessity of considering the effects of current and near future prices in explaining levels of current monthly hog marketings.

Slope coefficients for the inventory variables are interpreted in a manner similar to those for cattle inventory in the previous equation.

Net slope coefficients for the three months of a quarter are shown in Table II.

TABLE II

NET INVENTORY SLOPE COEFFICIENTS FOR THREE HOG INVENTORY WEIGHT CATEGORIES FOR FIRST, SECOND, AND THIRD MONTHS OF A QUARTER, DERIVED FROM EQUATION (2)

Month[a]	Weight Category, Pounds		
	60-119	120-179	180-219
1	65.604	-135.006	311.636
2	2.884	70.629	293.251
3	82.022	185.809	-174.509

[a]1 = December, March, June, and September.
2 = January, April, July, and October.
3 = February, May, August, and November.

It was expected that the heaviest weight class, 180-219 pounds, would have a decreasing influence on hog slaughter while the lighter classes, 120-179 and 60-119, would show a pattern of increasing influence through a three month quarter. These estimated coefficients for inventory of hogs demonstrate a pattern which is, for the most part, consistent with these expectations.

For the first month of a quarter the 180-219 pound weight class has a positive influence on hog slaughter while the 120-179 pound class has a negative influence.

In the second and third months the influence of the 120-179 pound class is positive and increasing while that of the 180-219 pound class decreases and becomes negative by the third month.

Contrary to expectations the influence of the 60-119 pound class is at first positive, decreases and then increases. However, as compared to the other two weight classes, the estimated coefficients for the 60-119 pound class are small in magnitude and relative to their standard errors, suggesting that hogs of this initial weight do not have appreciable effects on slaughter over an ensuing three month period.

The pattern of estimated monthly intercept dummy variables, adjusted for the effects of changes in the slopes of hog inventory variables, is shown in Figure 2.

Inventory numbers for hogs, as was the case for cattle, do not include all animals which are marketed for purposes of slaughter. In particular, the data for this variable exclude hogs outside the ten state survey area and all breeding stock. It is again felt that estimated monthly variations in quantity marketed, corrected for slope changes, arise from regular variations in excluded categories of potential slaughter animals.

In general, equation (2) indicates that monthly quantities of hogs marketed varies directly with quarterly inventory levels, time trend, and price of corn and inversely with expected change in the price of hogs. As the standard error of estimate for equation (2a) was only slightly larger than that for equation (2), even though the former equation was estimated excluding the two price variables. This would, as was the case for cattle marketings, seem to indicate either that the current and near future market price situation may play relatively minor roles in determining monthly hog marketings or the form of the price variable was incorrect.

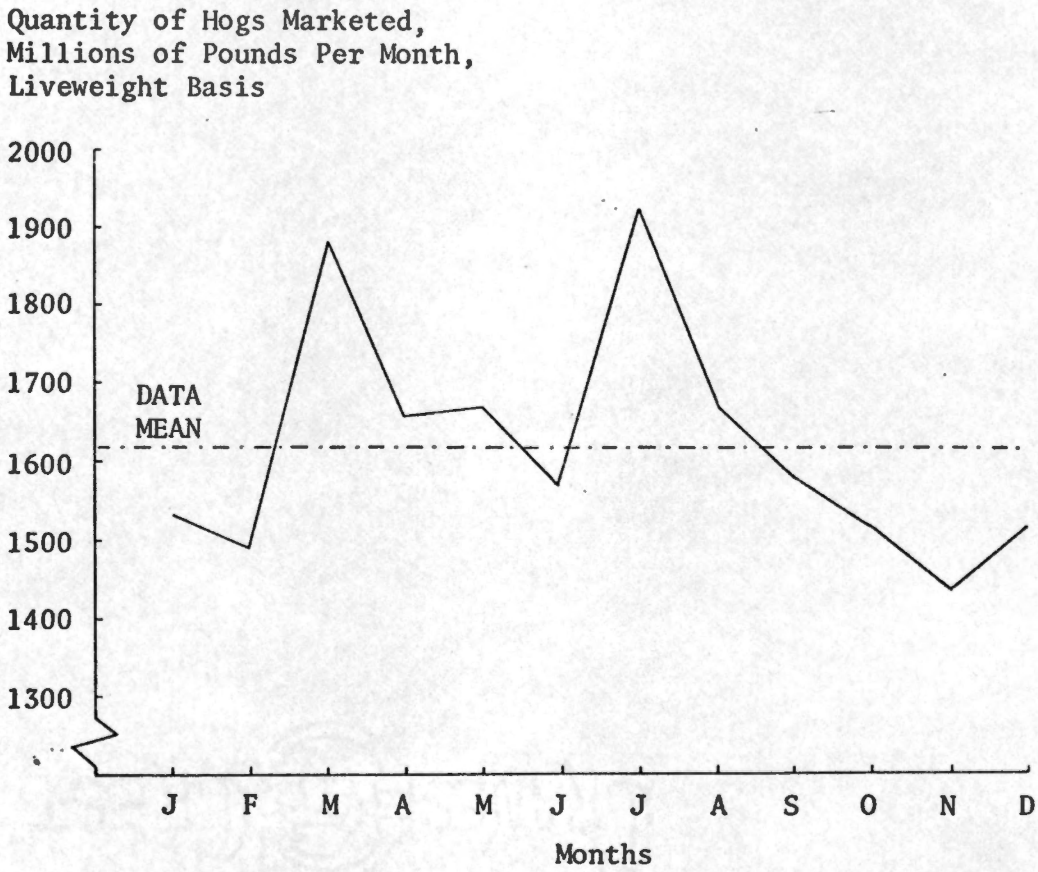

Figure 2. Adjusted monthly intercept values for equation (2).

The usefulness of equation (2a) in predicting levels of hog marketing will be assessed in the section of this chapter dealing with predictions generated by the model. Here the predictive ability of this equation will be compared to that of the reduced form equation which includes all predetermined variables.

Packer Level Price of Slaughter Cattle

The TSLS estimates for this equation are:

$$\begin{aligned}
\hat{P}_c^* = \; & \underset{(6.062)^*}{7.034} \; - \underset{(0.0016)}{0.0015} \, Q_c^{*d} \; + \underset{(0.069)^{**}}{0.482} \, P_{wb}^* \\
& - \underset{(0.007)}{0.005} \, \Delta CS_b^* \; - \underset{(1.597)^*}{2.735} \, W_p \; + \underset{(0.211)}{0.1935} \, WD \\
& + \underset{(0.057)^{**}}{0.193} \, PC \; + \underset{(0.021)^{**}}{0.051} \, T \; + \underset{(0.465)}{0.039} \, FEB \\
& + \underset{(0.493)}{0.401} \, MAR \; + \underset{(0.480)}{0.470} \, APR \; + \underset{(0.399)^*}{0.626} \, MAY \\
& + \underset{(0.374)^*}{0.621} \, JUN \; + \underset{(0.428)}{0.231} \, JUL \; + \underset{(0.393)}{0.255} \, AUG \\
& + \underset{(0.321)^*}{0.507} \, SEP \; + \underset{(0.358)}{0.121} \, OCT \; - \underset{(0.504)}{0.414} \, NOV \\
& - \underset{(0.504)}{0.356} \, DEC \qquad (3)
\end{aligned}$$

$\hat{\sigma}_e = 0.578$ (dollars per hundredweight)

With the exception of the sign of the coefficient for change in cold storage of beef (ΔCS_b^*), all variables of this equation have expected directions of influence. The fact that during the time period of this study the maximum change in cold storage of beef among all months was only 2 percent of average production coupled with the unexpected sign and insignificance for this coefficient suggests that meat packers may not consider cold storage of beef to be important in their buying of cattle.

A coefficient of -0.0015 for cattle slaughter (Q_c^{*d}) would indicate that for each one million pound rise in this variable slaughter steer prices fall by 0.15 cents. This estimated coefficient might indicate that, given the other variables in this equation, current quantity marketed may play a very minor role in explaining current cattle prices. That is, it would require a one billion pound change in cattle marketings to affect cattle price by $1.50 per hundredweight. A change of this magnitude in marketings is rather large, when compared to the data mean of 2.8 billion pounds per month for this variable.

A seemingly small degree of influence of monthly quantity of cattle on current market price of cattle would indirectly suggest that in the short run packing plants are flexible with respect to quantity of beef processed. That is, this coefficient implies that the packer demand curve, and thus the underlying marginal product curve of cattle, is nearly horizontal within the range of this study's data.

If deflated wholesale price (P_{wb}^*) is placed on a liveweight basis (by multiplying P_{wb}^* by $1/DP_c$) the coefficient for this variable becomes $0.825 = (0.482 \times 1/0.584)$. This implies that, neglecting by-product allowances, each dollar increase in deflated wholesale beef prices is associated with an 82.5 cent rise in the deflated price of live cattle, *ceteris paribus*.

A coefficient of -2.735 for deflated packer wages would indicate that for each $1.00 per hour rise in this cost packers respond by reducing deflated cattle prices by $2.735 per hundredweight.

As positive albeit insignificant coefficient for number of workdays (WD) would indicate that packers, in efforts to maintain a steady flow through their plants, may bid cattle prices up and down in accordance with the length of a working month.

As expected, when the composition of slaughter cattle changes to reflect a higher percentage of cows (PC) the deflated price of slaughter steers increases. The estimated coefficient would indicate that a 1 percent increase in the proportion of slaughter consisting of cows results in a 19 cent per hundredweight increase in deflated slaughter steer price, all else being equal.

An increase in the average quality level of slaughter steers, as reflected indirectly in time trend (T), has a positive influence on the deflated price of all slaughter steers, all else equal. As time trend does not vary exactly with quality, it is not possible to state from this equation the amount by which deflated cattle prices rise given an increase in quality.

Month to month variations in the overall intercept of equation (3) are shown graphically in Figure 3. It can be seen that given the effects of other variables which enter this equation steer prices tended to be somewhat higher than average in spring through early fall months and lower than average in other months, especially November and December.

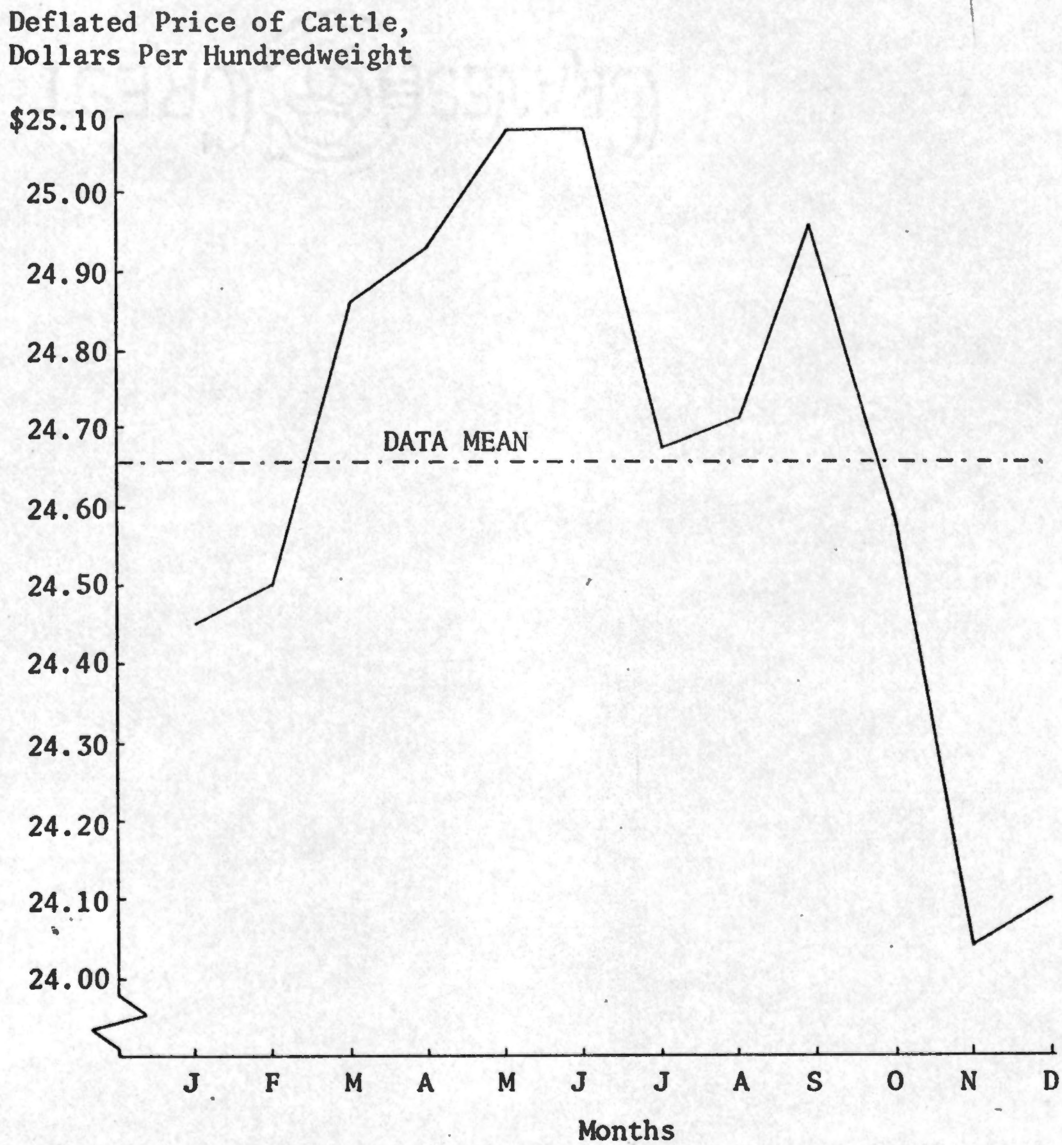

Figure 3. Monthly intercept levels of equation (3).

Although the spread of these monthly variations is somewhat small, about \$1.14 or roughly 11 percent of the data range for deflated steer prices, it is interesting that they exist at all, given effects of other variables in the equation. The fact that there are no wide or statistically significant differences in month to month average prices, given the other variables of this equation, would suggest that the other variables included in the equation account for most of the systematic monthly variation in cattle prices, or there was not much of such variation present in the original data.

It is felt that the primary variations measured by the monthly variables in this equation arise from the fact that the cattle price, slaughter weight, and wholesale beef price variables are based on data from different geographical areas. Thus, the monthly dummies may in part measure any regular monthly variations in the regional distribution of prices and slaughter.

<u>Packer Level Price of Slaughter Hogs</u>

The estimated equation is:

$$\begin{aligned}
\hat{P}_h^* = & \underset{(4.326)^*}{-\ 8.523} \quad \underset{(0.0030)}{-\ 0.0028}\ Q_h^{*d} \quad \underset{(0.056)^{**}}{+\ 0.609}\ P_{wp}^* \\
& \underset{(0.008)}{+\ 0.002}\ \Delta CS_p^* \quad \underset{(1.284)}{-\ 0.142}\ W_p \quad \underset{(0.274)}{+\ 0.187}\ WD \\
& \underset{(0.123)}{+\ 0.054}\ PS \quad \underset{(0.562)}{+\ 0.499}\ FEB \quad \underset{(0.499)}{+\ 0.409}\ MAR \\
& \underset{(0.558)}{+\ 0.203}\ APR \quad \underset{(0.579)}{+\ 0.231}\ MAY \quad \underset{(0.726)}{-\ 0.026}\ JUN
\end{aligned}$$

$$- \underset{(0.847)}{0.199}\ JUL \quad - \underset{(0.714)}{0.231}\ AUG \quad - \underset{(0.484)}{0.051}\ SEP$$

$$+ \underset{(0.443)}{0.223}\ OCT \quad - \underset{(0.519)}{0.401}\ NOV \quad - \underset{(0.467)}{0.300}\ DEC \qquad (4)$$

$\hat{\sigma}_e = 0.792$ (dollars per hundredweight)

All estimated parameters of this equation agree with a priori expectations with respect to sign. However, with the exception of the coefficient for wholesale price of pork, none of these can be considered statistically significant.

The estimated coefficient of -0.0028 for liveweight quantity of hogs slaughtered (Q_h^{*d}) would suggest that a one billion pound increase in this variable is associated with a \$2.80 decrease in the price of barrows and gilts. Such a change would represent a considerable variation in the monthly quantity of hogs slaughtered, as the mean for this variable was only 1.68 billion pounds.

Thus, as was the case for cattle, the demand curve for hogs at the packer level is nearly horizontal. Again, this is taken as a reflection of a nearly horizontal marginal product curve for hogs over the range of data included in this study.

If deflated wholesale pork price (P_{wp}^*) is placed on a liveweight price basis (by multiplying P_{wp}^* by $1/DP_h$) the coefficient for this variable becomes $0.866 = (0.609 \times 1/0.703)$. This implies that for every dollar increase in the deflated wholesale price of pork there is, neglecting by-product allowances, an associated 86.6 cents per hundredweight rise in the deflated price of liveweight hogs, ceteris paribus.

The coefficient for change in cold storage of pork (ΔCSP), unlike the analogous variable in equation (3), has a theoretically correct positive sign. Again, however, the coefficient is much smaller than its standard error. Furthermore, the size of the estimated coefficient would suggest that it requires a one billion pound change in cold storage of pork to result in a $2.00 per hundredweight change in the deflated price of barrows and gilts. It is unlikely that this variable had any large impact on hog prices when it is considered that the maximum month to month change observed for this variable was only 93.3 million pounds.

A coefficient of -0.142 for deflated packer wages (W_p) indicates that as labor costs increase, packers in part pass this back to hog producers in the form of lower prices. Again, however, this coefficient is much smaller than its standard error, thus must be interpreted with considerable caution.

As the number of packer workdays (WD) increases the estimated coefficient for this variable indicated that deflated hog prices tend to increase somewhat.

As the percentage of sows (PS) increases, the positive coefficient for this variable would indicate that the deflated price of barrows and gilts tends to increase. This relationship should also be interpreted with caution, as the magnitude of the estimated coefficient is again much smaller than its standard error.

Coefficients estimated for the monthly dummy variables, as shown in Figure 4, indicate that hog prices, given the effects of other

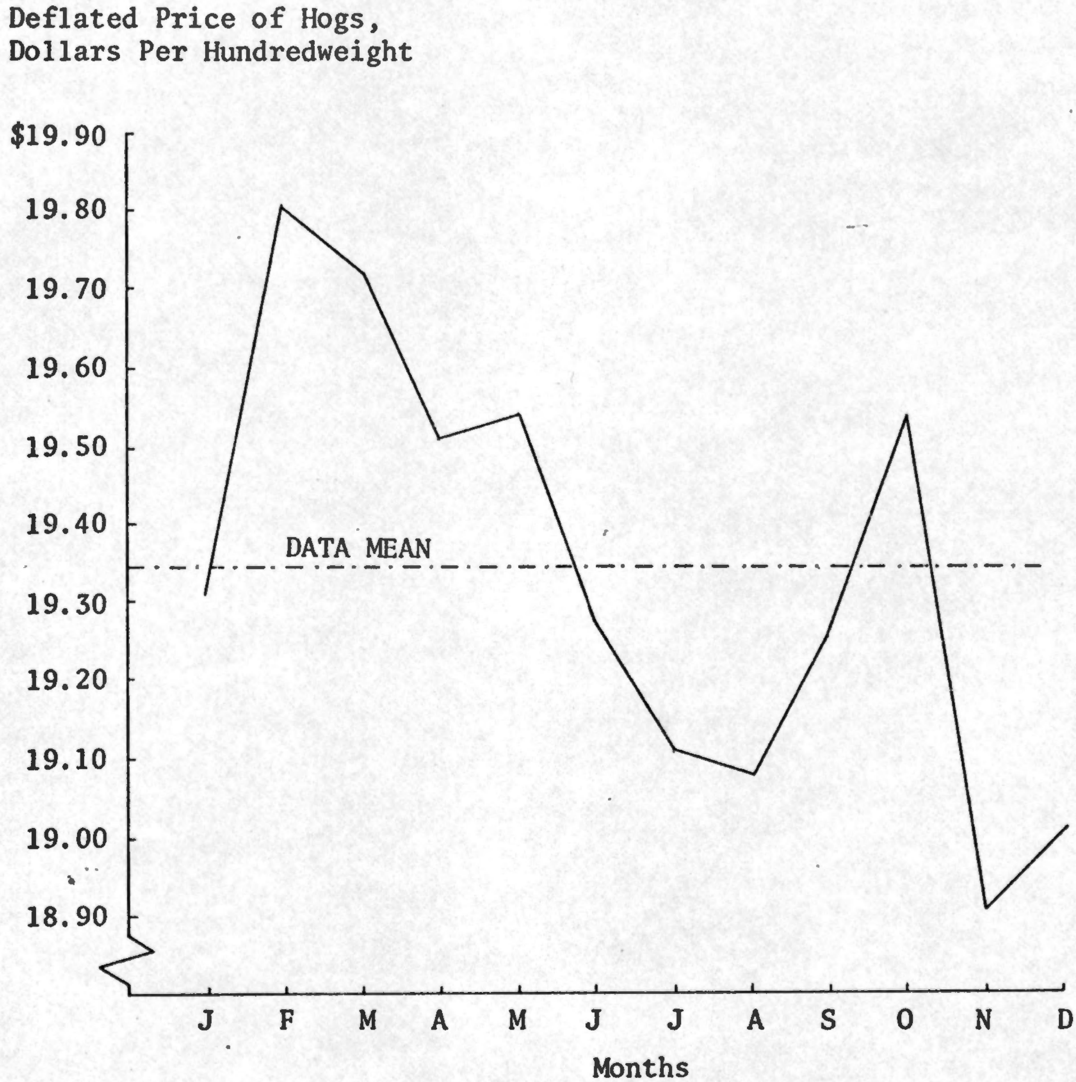

Figure 4. Monthly intercept levels of equation (4).

variables in the equation, tend to be higher than average in the spring, early summer, and the month of October.

Given the effects of other variables, the monthly intercept of the equation changes by only about 90 cents per hundredweight from the highest month (February) to the lowest month (November). The maximum variation in intercepts among all months amounts to only about 6 percent of the range in deflated hog prices, and thus is not considered to be an important component of variations in slaughter hog price. As was mentioned in the discussion of the previous equation, packer demand for cattle, it is felt that the monthly variations in intercept arise from the differing geographical areas on which the price and quantity variables are based.

In general, the impression which arises from the set of coefficients estimated for this equation is that one variable, the wholesale price of pork, dominates the behavior of the packing industry in the pricing of hogs. All other variables in this equation had estimated coefficients which were small relative to both their standard errors and impact on the deflated price of hogs.

<u>Change in Cold Storage of Beef</u>

This equation, as estimated by TSLS, is:

$$
\begin{aligned}
\Delta\hat{CS}_b^* = {} & \underset{(36.676)}{32.847} - \underset{(0.781)^{**}}{2.278}\, P_{wb}^* + \underset{(5.369)}{0.417}\, P_c^{*e\Delta} \\
& + \underset{(0.017)^{**}}{0.050}\, Q_{pb}^* - \underset{(0.038)^{**}}{0.096}\, CS_{b(t-1)} - \underset{(7.802)}{3.664}\ \text{FEB} \\
& - \underset{(7.138)}{4.225}\ \text{MAR} - \underset{(7.338)}{6.808}\ \text{APR} - \underset{(7.181)^{*}}{8.847}\ \text{MAY}
\end{aligned}
$$

$$- \underset{(7.244)^*}{8.632}\ JUN + \underset{(7.409)}{1.855}\ JUL + \underset{(7.381)}{2.066}\ AUG$$

$$+ \underset{(7.723)}{3.771}\ SEP + \underset{(7.512)^*}{8.815}\ OCT + \underset{(7.389)^{**}}{21.068}\ NOV$$

$$+ \underset{(7.045)^{**}}{18.967}\ DEC \qquad (5)$$

$\hat{\sigma}_e = 13.088$ (millions of pounds)

All coefficients of this equation agree with a priori expectations relative to sign.

A coefficient of -2.278 for deflated wholesale price of beef (P^*_{wb}) would indicate that a one dollar per hundredweight increase in this variable results in a net outmovement of 2.278 million pounds of beef cold storage from first of month to last of month.

On the other hand, if cattle prices ($P_c^{*e\Delta}$) are expected to rise by one dollar per hundredweight a net inmovement of 0.417 million pounds of beef cold storage is indicated.

Given that the production of beef (Q^*_{pb}) rises, the estimated coefficient for this variable would indicate a net inmovement of beef cold storage. For each one million pound rise in production, beef cold storage rises by 0.05 million pounds from first of month to end of month.

As first of month stocks of beef cold storage ($CS_{b(t-1)}$) rise there tends to be an outmovement of cold storage during that month. The estimated coefficient for this variable would indicate that a one million pound increase in beginning inventory results in a 0.096 million pound outmovement in beef cold storage.

The estimated monthly intercept change coefficients indicate monthly movement in beef cold storage relative to the omitted month of January. Coefficients for the monthly dummy variables are plotted against the data mean for change in cold storage in Figure 5. Given the effects of other variables which enter this equation there are net out-movements of beef cold storage during the first six months of a year and net inmovements during the last six months. The relatively small magnitude of these coefficients is indicative of a characteristic of beef cold storage stocks, that is, they are fairly stable from month to month.

<u>Change in Cold Storage of Pork</u>

The TSLS estimates for this equation are:

$$
\begin{aligned}
\Delta\hat{CS}_p^* = {} & \underset{(82.224)^{**}}{230.308} - \underset{(1.038)^{**}}{4.031}\, P^*_{wp} + \underset{(16.290)^{*}}{23.549}\, P_h^{*e\Delta} \\
& + \underset{(0.029)^{*}}{0.034}\, Q^*_{pp} - \underset{(0.071)^{**}}{0.255}\, CS_{p(t-1)} + \underset{(9.921)^{*}}{13.539}\, FEB \\
& - \underset{(9.908)}{0.984}\, MAR + \underset{(10.183)^{**}}{30.599}\, APR + \underset{(12.155)}{11.341}\, MAY \\
& - \underset{(12.926)^{**}}{28.584}\, JUN - \underset{(11.604)^{**}}{48.668}\, JUL - \underset{(10.648)^{**}}{66.624}\, AUG \\
& - \underset{(10.624)^{**}}{50.466}\, SEP - \underset{(10.672)^{*}}{25.538}\, OCT - \underset{(9.541)}{7.669}\, NOV \\
& \underset{(9.089)}{0.690}\, DEC \qquad (6)
\end{aligned}
$$

$$\hat{\sigma}_e = 16.428 \text{ (millions of pounds)}$$

Signs of all estimated coefficients for this equation agree with <u>a priori</u> expectations.

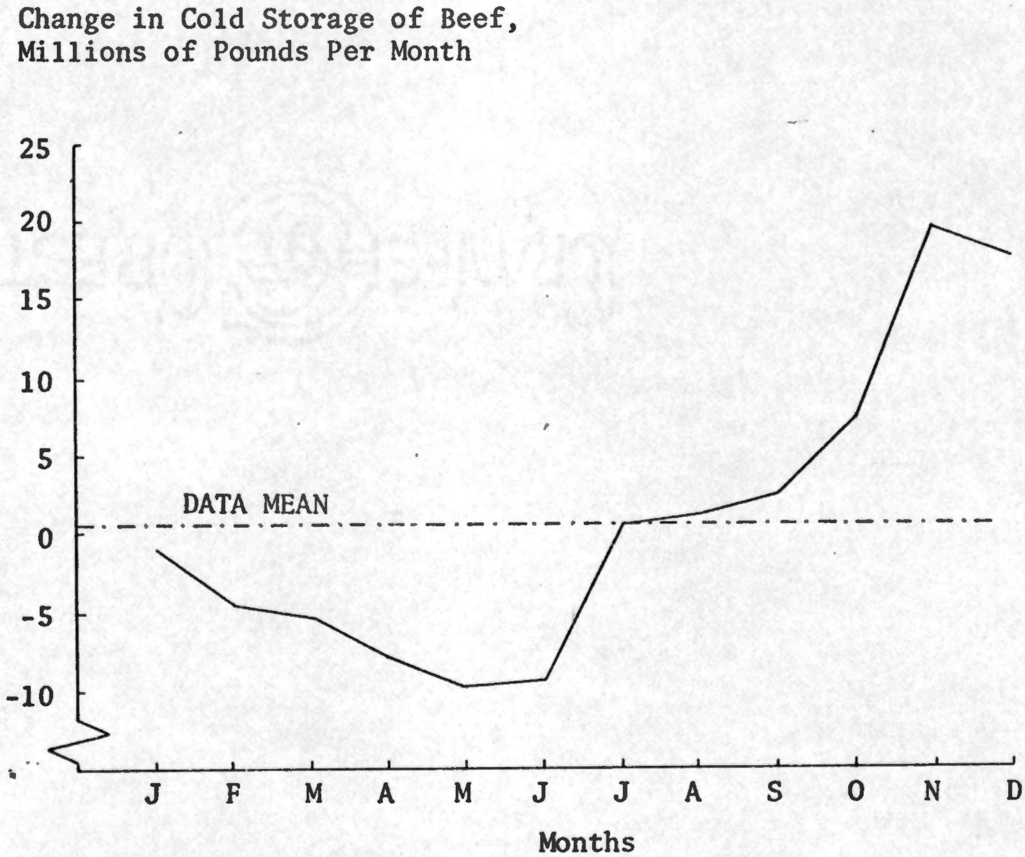

Figure 5. Monthly intercept levels of equation (5).

The estimated coefficient for deflated wholesale price of pork (P^*_{wp}) in this equation indicates that cold storage of pork decreases by 4.031 million pounds for each one dollar per hundredweight increase in this price. On the other hand, if hog prices ($P_h^{*e\Delta}$) are expected to rise by one dollar per hundredweight cold storage of pork responds by increasing 23.549 million pounds.

As the quantity of pork produced (Q^*_{pp}) increases the coefficient estimated for this variable indicates a 0.034 million pound inmovement of pork cold storage for each one million pound increase.

For each one million pound increase in beginning inventory of pork storage ($CS_{p(t-1)}$) there is a net outmovement of 0.255 million pounds of pork storage in the ensuing month.

Coefficients estimated for the monthly intercept dummy variables are interpreted as net movements in pork cold storage given the effects of other variables in this equation. Figures which appear for these coefficients in equation (6) are measured relative to the change in the deleted or base month of January. Figure 6 illustrates the pattern of monthly intercepts measured relative to the data mean for change in cold storage of pork. Net inmovements of pork cold storage occur in the late and early parts of a year with net outmovement during the months of June through October, given the effects of other variables in this equation.

Generally, pork cold storage responds as expected to the variables which appear on the right hand side of this equation. It is somewhat unusual that change in pork cold storage does not seem important to

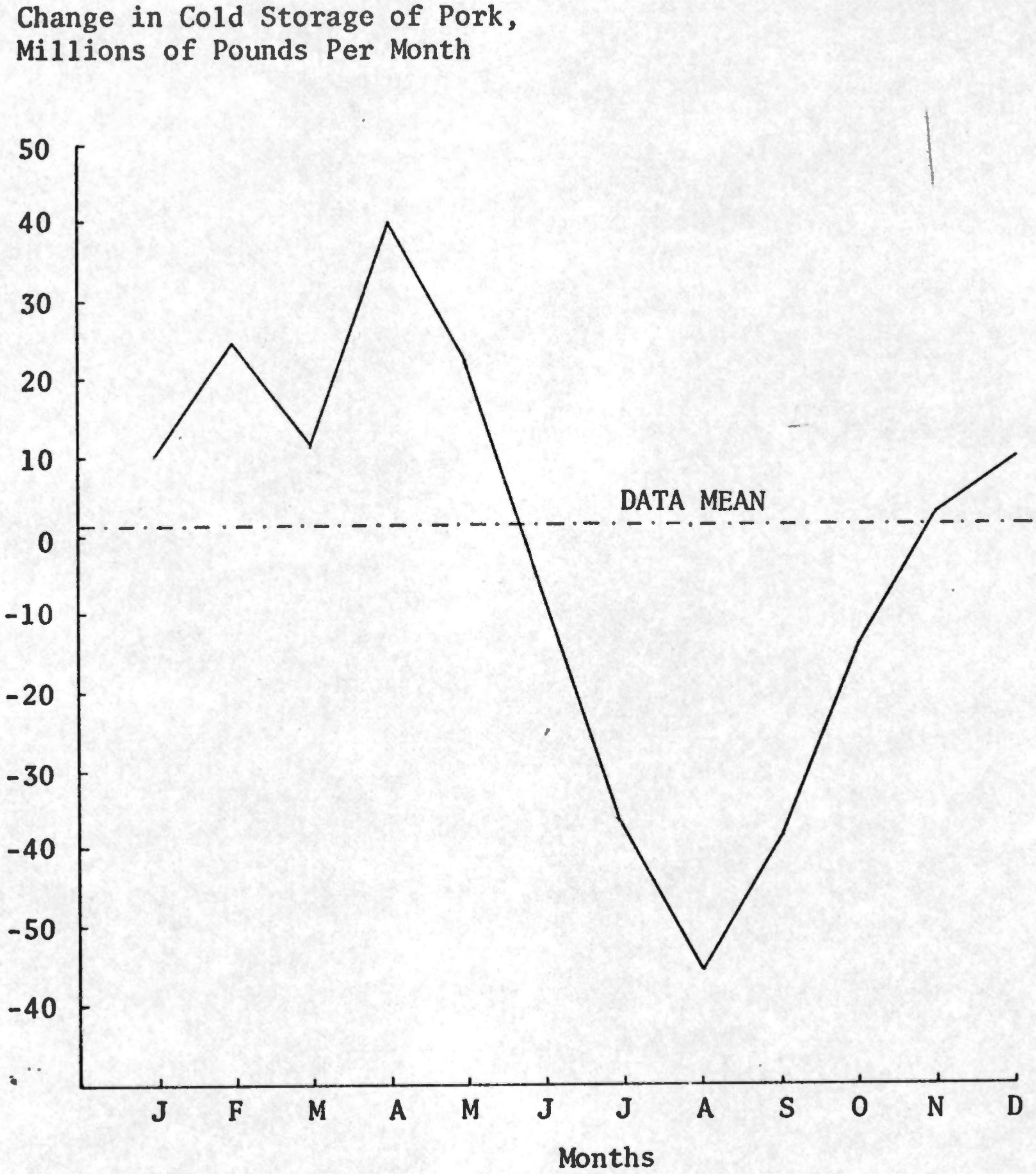

Figure 6. Monthly intercept levels of equation (6).

packers in establishing the price of hogs, while at the same time packers do seem to respond to economic forces in establishing levels of storage of pork.

<u>Wholesale to Retail Marketing Margin for Beef</u>

The TSLS estimates of the coefficients of this equation are:

$$\hat{M}_b^* = \underset{(5.139)}{-\,2.497} + \underset{(0.0036)}{0.0004}\ C_b^* - \underset{(0.086)^{**}}{0.378}\ P_{wb}^*$$

$$+ \underset{(4.252)^{**}}{17.516}\ W_r \qquad (7)$$

$$\hat{\sigma}_e = 1.407 \text{ (cents per pound)}$$

All estimated coefficients of this equation agree with *a priori* expectations with respect to sign.

A small and insignificant coefficient for beef consumption (C_b^*) indicates that the margin did not change appreciably with changes in this variable, given the other variables which appear. This, of course, does not at all imply that wholesale and retail prices or beef are insensitive to changes in quantity marketed of beef, but rather that the two prices move up and down by almost equal dollar amounts as quantity marketed changes.

The wholesale to retail marketing margin for beef responds in an inverse manner to changes in deflated wholesale price of beef (P_{wb}^*). A magnitude of -0.378 for this coefficient indicates that as deflated wholesale beef price decreases by 1 cent per pound, this margin increases by amount 0.38 cents per pound. That is, this coefficient implies that given a change in the wholesale price of beef, retail price will change in the same direction but not by as great a dollar amount. Thus, this coefficient would indicate that beef retailers tend to absorb a portion of wholesale price rises, but given a fall in wholesale price only a portion of this is passed along to consumers in the form of lower retail prices.

The positive coefficient for deflated wages would indicate that retailers have widened their margin on beef by 0.175 cents for each 1.0 cent increase in this cost, ceteris paribus. With the increase in deflated retail wages of 22.34 cents per hour which occurred during the period covered by this study an increase in the deflated beef margin of 3.924 cents per pound is indicated. In other words increased labor costs have been passed along to beef consumers in the form of higher retail prices and/or beef packers in the form of lower wholesale prices.

Wholesale to Retail Marketing Margin for Pork

The estimated equation is:

$$\hat{M}^*_p = \underset{(4.302)^*}{-4.555} + \underset{(0.0021)^*}{0.0032}\, C^*_p + \underset{(0.043)}{0.035}\, P^*_{wp} + \underset{(2.914)^*}{6.785}\, W_r \qquad (8)$$

$$\hat{\sigma}_e = 1.304 \text{ (cents per pound)}$$

All coefficients estimated for this equation agree with a priori expectations relative to sign.

The coefficient for pork consumption (C_p^*) implies that a one billion pound increase in monthly quantity consumed would result in a 3.2 cent (with a mean margin of 13.48 cents) increase in the deflated wholesale to retail margin, <u>ceteris paribus</u>. Such an increase in C_p^* would represent an almost doubled consumption of pork over the mean of this variable during the study period.

A small and insignificant coefficient for deflated wholesale price of pork (P_{wp}^*) indicates that the pork margin did not change much given a change in this variable. The fact that the estimated coefficient is positive implies that a 1 cent per pound change in the deflated wholesale price of pork is associated with a 1.035 cents per pound increase in the deflated retail price of pork. In a broader sense, this means that pork retailers respond in an almost neutral manner to changes in wholesale prices, given the other variables in this equation.

Thus there appears, with respect to the respective coefficients for wholesale prices, to be a difference between the behavior of beef and pork margins. Perhaps, given the difference in the nature of services performed by retailers on the two meats, this result should not be surprising. Retailers for the most part receive beef in carcass form, and must perform many of the necessary operations in transforming the product to retail cuts. On the other hand, pork is received by most retailers in the form of wholesale cuts which require relatively few operations for transformation into retail pork products.[4]

---

[4]This fact is also reflected in the data means for the two margins, 16.33 cents per pound for beef and 13.48 cents per pound for pork.

Thus, given a 1 cent per pound price rise for wholesale pork the retailer, whose services here consist mainly of providing display space, must pass along the increase to consumers. On the other hand, the retailer of beef, operating on a wider margin and providing more in the way of services, could be in a position to absorb some portion of a 1 cent per pound rise in wholesale beef price.

A positive coefficient for deflated retail wages in this equation indicates that retailers widened their margin for pork in response to increase in this cost. A 1 cent increase in deflated wages resulted in a 0.0679 cent increase in deflated margins. Thus, within the increase in deflated retail wages of 22.34 cents per hour which occurred during the period of this study an increase in the deflated pork margin of about 1.54 cents is indicated, ceteris paribus.

As was the case for wholesale price, the beef margin seems to be more sensitive to changes in this variable than does the pork margin. Again, this may be taken as indicative of the higher retail labor component in retail beef as opposed to retail pork.

Retail Demand for Beef

The TSLS estimates of the coefficients of this equation are:

$$\hat{C}_b^{*pc} = \underset{(1.129)^{**}}{5.427} - \underset{(0.013)^{**}}{0.041}\, P^*_{rb} + \underset{(0.007)^{*}}{0.012}\, P^*_{rp}$$

$$+ \underset{(0.025)}{0.011}\, P^*_{rbr} + \underset{(0.003)^{**}}{0.015}\, I^{pc} - \underset{(0.106)^{**}}{0.666}\, FEB$$

$$- \underset{(0.110)^{**}}{0.296}\, MAR - \underset{(0.110)^{**}}{0.372}\, APR - \underset{(0.105)^{*}}{0.197}\, MAY$$

$$- 0.111\ JUN \underset{(0.105)^*}{} - 0.198\ JUL \underset{(0.107)^*}{} - 0.131\ AUG \underset{(0.106)^*}{}$$

(0.105)* (0.107)* (0.106)*

$$- 0.070\ SEP + 0.097\ OCT - 0.513\ NOV$$

(0.106) (0.103) (0.104)**

$$- 0.316\ DEC \qquad (9)$$

(0.104)**

$$\hat{\sigma}_e = 0.193 \text{ (pounds)}$$

All estimated coefficients for this equation agree with a priori expectations relative to sign.

Subject to the qualifications mentioned earlier with respect to the interpretation of estimated structural parameters, price, cross price and income elasticities for beef were computed from equation (9).[5]

Direct price elasticity was computed as -0.5004, implying that a 1 percent rise in the deflated retail price of beef is accompanied by about a .5 percent decrease in per capita beef consumption, *ceteris paribus*.

Cross price elasticities for pork and broilers were computed as 0.1173 and 0.0624, respectively. Thus, a 1 percent increase in the deflated retail price of pork or broilers implies about a 0.12 or 0.06 percent increase in per capita beef consumption. The computed cross elasticity for broilers is suspect as the structural coefficient upon which it is based is not economically significant.

---

[5] In equation (9) elasticity for a variable Z was computed as $E = (\partial Q_b^{*}pc/\partial Z)\cdot(\overline{Z}/\overline{Q_b^{*}pc})$ where $(\partial Q_b^{*}pc/\partial Z)$ is the structural coefficient of variable Z while $\overline{Z}$ and $\overline{Q_b^{*}pc}$ are the data means of these two variables.

Income elasticity of per capita beef consumption was computed as 0.5644, implying that a 1 percent rise in deflated per capita income is accompanied by about 0.56 percent increase in per capita beef consumption, *ceteris paribus*.

During the period covered by this study deflated per capita personal income increased from $194.40 per month to $245.40 per month, that is, by $51.00 per month. The estimated structural coefficient for income of 0.015 would indicate that a 0.765 pound per month increase in per capita beef consumption in response to this change, *ceteris paribus*.

Thus, these results indicate that, with respect to the demand for beef, ~~is that~~ quantity consumed of this commodity is inelastic with respect to changes in its price, the price of close substitutes, and income.

The estimated coefficients of the monthly dummy intercept variables are shown in graphical form in Figure 7. Given the effects of other variables in this equation, per capita beef consumption tends to be below its data mean during the early and late portions of the year and above the data mean for the months of May through October and the month of January.

Retail Demand for Pork

The TSLS estimates of the coefficients of this equation are:

$$\hat{C}^{*pc}_{p} = \underset{(1.312)^{**}}{7.876} - \underset{(0.008)^{**}}{0.066}\, P^{*}_{rp} - \underset{(0.015)^{*}}{0.018}\, P^{*}_{rb}$$

$$+ \underset{(0.029)}{0.026}\, P^{*}_{rbr} + \underset{(0.0036)^{**}}{0.0092}\, I^{pc} - \underset{(0.123)^{**}}{0.769}\, FEB$$

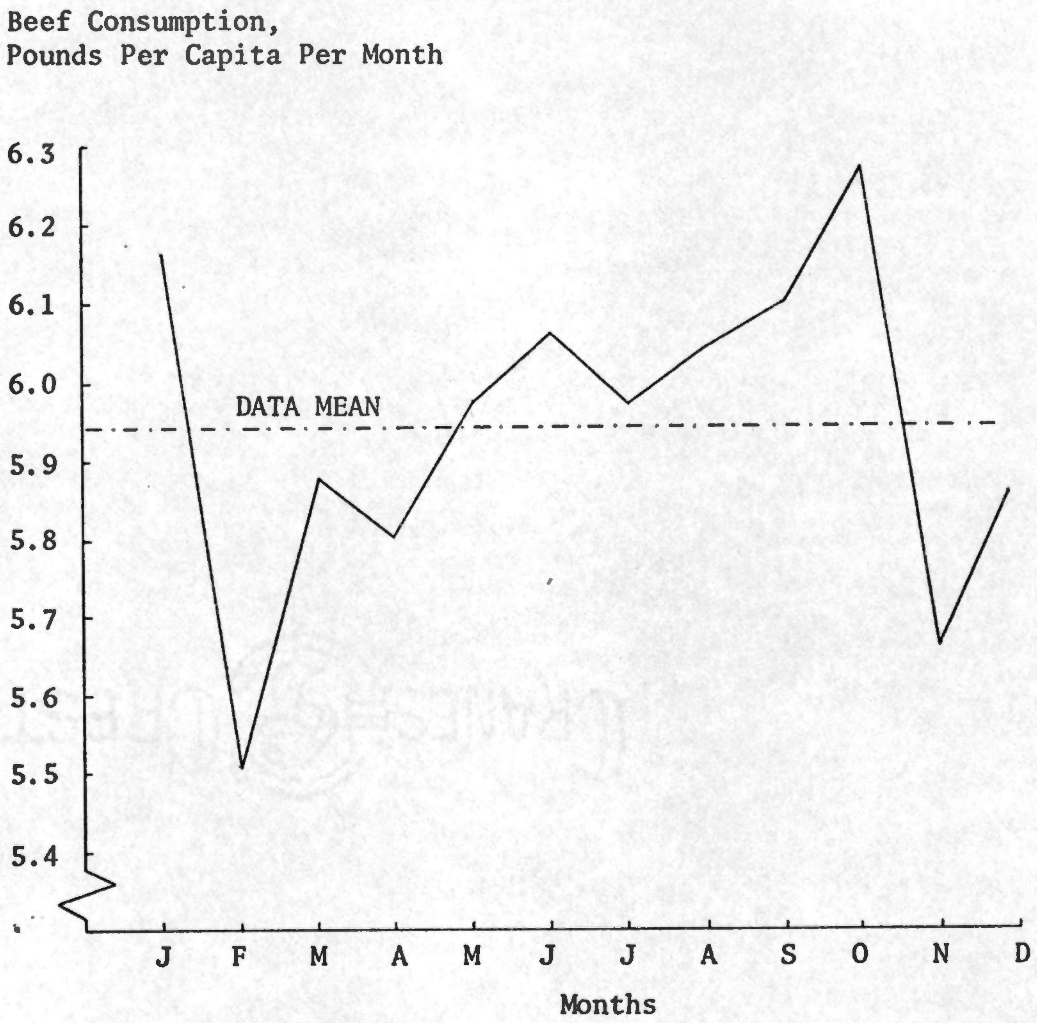

Figure 7. Monthly intercept levels of equation (9).

- 0.135 MAR (0.127)*	- 0.432 APR (0.129)**	- 0.580 MAY (0.122)**
0.550 JUN (0.122)*	- 0.630 JUL (0.124)**	- 0.411 AUG (0.123)**
- 0.127 SEP (0.123)*	+ 0.211 OCT (0.120)*	- 0.091 NOV (0.120)
+ 0.058 DEC (0.121)		

(10)

$\hat{\sigma}_e = 0.224$ (pounds)

Except for the coefficient for deflated retail price of beef, all estimated parameters for this equation possess theoretically correct signs.

Results similar to this were obtained by Hayenga and Hacklander (1970). In their model of the beef-pork sector quantities of beef and pork appeared as right hand side variables in packer demand equations, with no retail demand equations being specified. In their beef demand function the estimated coefficient indicated that cattle and hogs were substitutes, whereas in the pork demand equation estimated coefficients were indicative of a complementary relationship. On the other hand, the results of the Myers study (1968) indicate that beef and pork are mutual substitutes.

It is somewhat implausible that consumers would, in one case consider the two meats to be substitutes and in another case, complements. The estimated coefficient for beef price—having both an incorrect sign and being statistically insignificant—is rejected as being representative of the actual relationship which exists between this variable and pork consumption.

Direct price elasticity for pork was computed as -0.7162 with cross-elasticities of -0.3497 and 0.1628 for beef and broilers, respectively. Income elasticity was calculated as 0.3835. These results would thus indicate that pork, like beef, is price and income elastic.

The $51.00 increase in deflated per capita monthly personal income which took place during the study period would imply a resulting 0.4677 = (51.00 × 0.0092) pound per month increase in per capita consumption of pork, ceteris paribus.

Estimated coefficients for the monthly intercept dummy variables for equation (10) are shown in Figure 8. In general, the pattern evident here is one of depressed, below average consumption of pork in the months of April through August and February, given the effects of other variables in this equation.

Unlike the monthly patterns of equations (1) and (9), cattle slaughter and beef consumption, the monthly intercept levels of equations (2) and (10), hog slaughter and pork consumption, do not seem to move in a similar pattern, especially during the latter part of the year. For instance, both graphs display low points for intercepts in February and higher points in March; however, there is a distinct peak in the intercept of equation (2) in July while the graph for intercepts of equation (10) show a low point in that month. Thus it is not possible to state, even tentatively, that these two equations are influenced by some common omitted variable.

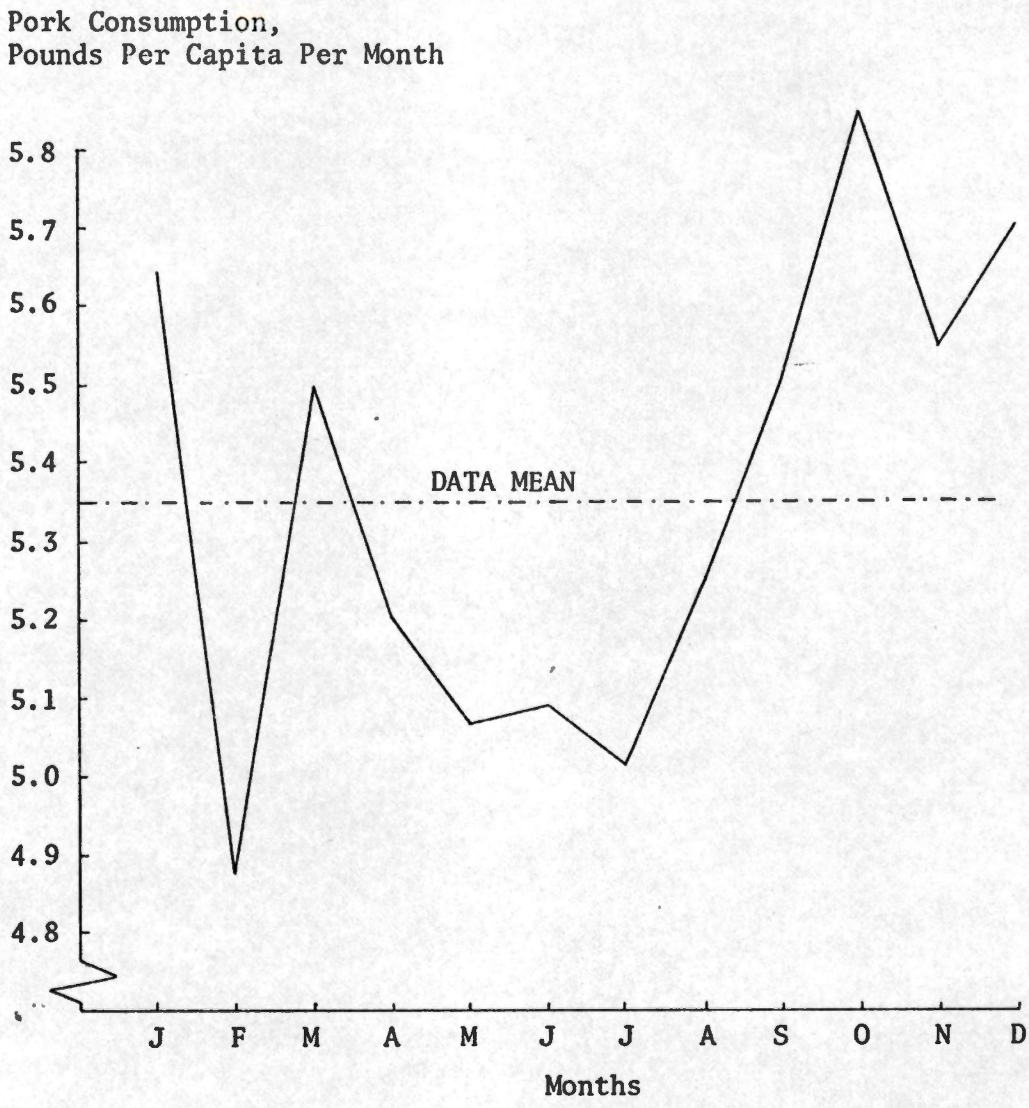

Figure 8. Monthly intercept levels of equation (10).

Retail Demand for Broilers

The TSLS estimates of the coefficients of this equation are:

$$\hat{P}^*_{rbr} = \underset{(4.104)^{**}}{32.976} - \underset{(0.780)^{**}}{3.288}\ C^{pc}_{br} + \underset{(0.069)^{**}}{0.155}\ P^*_{rb}$$

$$+ \underset{(0.028)^{**}}{0.192}\ P^*_{rp} - \underset{(0.014)^{**}}{0.062}\ I^{pc}$$

$$+ \underset{(0.607)}{0.179}\ FEB + \underset{(0.584)^{*}}{1.168}\ MAR + \underset{(0.583)^{**}}{1.615}\ APR$$

$$+ \underset{(0.595)^{*}}{1.170}\ MAY + \underset{(0.616)^{**}}{1.585}\ JUN + \underset{(0.599)^{**}}{1.349}\ JUL$$

$$+ \underset{(0.617)^{**}}{1.410}\ AUG + \underset{(0.595)^{*}}{1.170}\ SEP + \underset{(0.609)^{*}}{0.786}\ OCT$$

$$- \underset{(0.624)^{*}}{1.097}\ NOV - \underset{(0.590)}{0.357}\ DEC \qquad (11)$$

$\hat{\sigma}_e = 1.082$ (cents per pound)

All coefficients estimated for this equation agree with a priori expectations with respect to sign.

Direct price flexibility for broilers was computed as -0.256, while income flexibility[6] was calculated as -0.405. These results imply that a 1 percent increase in per capita consumption is associated with a 0.256 percent decrease in deflated retail broiler prices. A 1 percent increase in deflated per capita income is associated with a 0.405 percent decrease in the deflated retail price of broilers.

---

[6] Flexibility is computed as $(\partial P^*_{rbr}/\partial Z)\cdot(\overline{Z}/\overline{P}^*_{rbr})$ where $(\partial P^*_{rbr}/\partial Z)$ is the coefficient of variable Z in equation (11) and $\overline{Z}$ and $\overline{P}^*_{rbr}$ are the arithmetic means of Z and P^*_{rbr}, respectively.

Houck (1965) shows that by inverting estimated price flexibility an approximation of price elasticity may be obtained. This approximation is shown to be the lower limit of the true elasticity. Thus for the present study the inverse of the estimated price flexibility indicates a lower limit of -3.91 for price elasticity of broilers. While this result might indicate that per capita broiler consumption is price elastic, there is no guarantee that this is actually the case.

Figure 9 shows the pattern of the monthly intercepts for this equation. The pattern here is one of broilers price being above average for the months of May through September and below average for the remainder of the year, given the effects of other variables in this equation.

III. TRENDS IN ELASTICITIES

Retail price and income elasticities computed from the estimated model of this study are shown in Table III. Also shown here are elasticities computed from several past studies.

Although the studies summarized here used a variety of estimating techniques some trends in elasticities are evident. It would appear that the demand for beef is becoming increasingly price and income inelastic through time. While there is a trend evident toward a more inelastic demand for pork, income elasticity by pork has been estimated as positive only in studies which included data from the 1960's.

Income elasticity for broilers has been declining through time while at the same time, price elasticity for broilers seems to contain no strong trend in either direction.

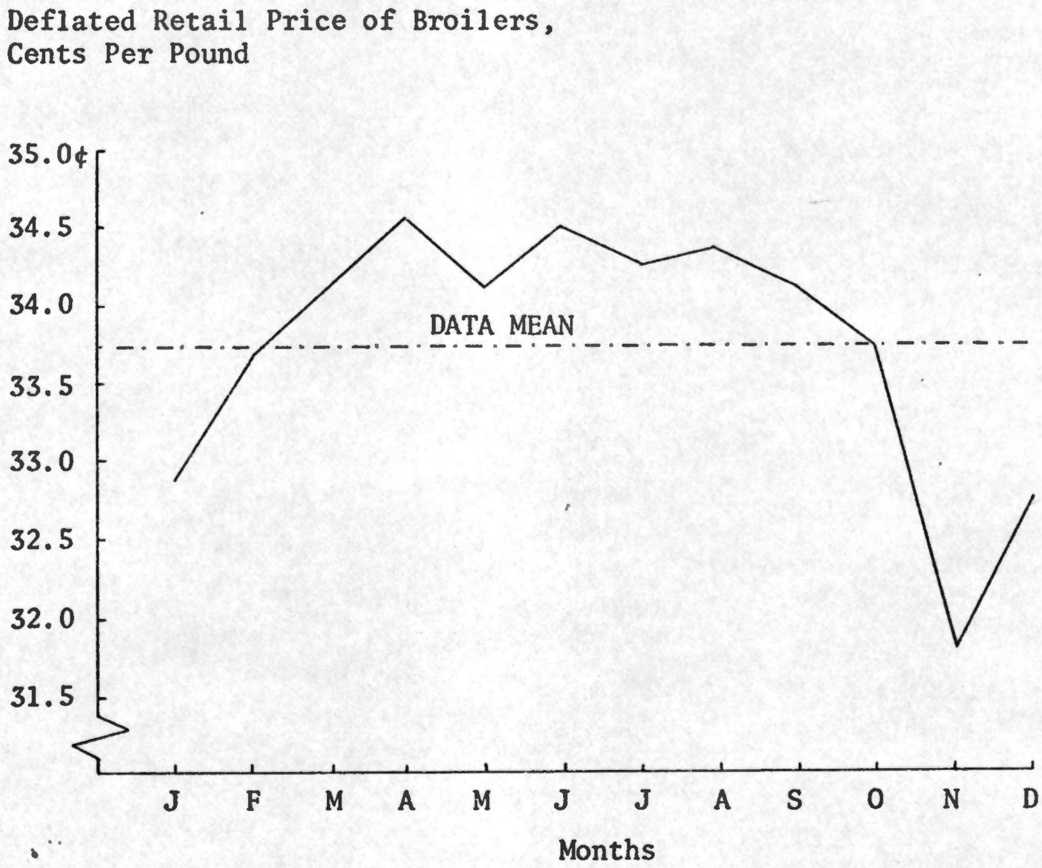

Figure 9. Monthly intercept levels of equation (11).

TABLE III

RETAIL PRICE AND INCOME ELASTICITIES FOR BEEF, PORK AND BROILERS FROM SELECTED PREVIOUS STUDIES

Study	Beef		Pork		Broilers		Years	Observation	Estimation
	Price	Income	Price	Income	Price	Income	Included	Period	Method
Stanton (1961)	-1.76	-0.83	-1.83	-1.85	-1.26 to -2.24	0.31 to 3.36	1953-1959	Quarters	I.L.S.[a]
Logan and Boles (1962)	-0.62 to -0.64	Pos.[b]	-0.91 to -1.25	Neg.[b]	-2.54 to -3.07	Pos.[b]	1948-1959	Quarters	I.L.S.[a]
Farris and Darley (1964)					-1.10[c]		1953-1963	Months	O.L.S.
Myers (1968)	-0.73 to -0.67	1.12 to 1.03	-0.84 to -0.64	0.33 to 0.27	-1.34 to -1.76	0.86 to 0.65	1949-1966	Months	T.S.L.S.
Hayenga and Hacklander (1970)	-0.91[c,d]	Pos.[b]	-0.63[c,d]	Pos.[b]			1963-1968	Months	T.S.L.S.
Elam (1973)	-0.50	0.56	-0.72	0.47	-3.91[d]		1964-1970	Months	T.S.L.S.

[a]Indirect least squares.

[b]Actual value not reported.

[c]Derived from farm level relationship.

[d]Calculated by inverting estimated flexibility.

IV. TEST OF THE MODEL USING POSTSAMPLE PERIOD DATA

Two objectives of this study were to test the model using data for early 1972 and to determine the usefulness of recently begun inventory series on cattle and hogs in analyzing variations in quantities of the two animals marketed.

With respect to the first objective, the first stage reduced form equations of the model, as estimated using data from January 1964 through December 1970 will be used to calculate values for the endogenous variables for the period January 1971 through April 1972. The abilities of the estimated model in tracking actual values of the endogenous variables during this new period will be an indication of the degree of faith which may be placed in other results of this study.

The specific method used to obtain calculated values involves the first stage equations of the two stage least squares method. Here, each endogenous variable is regressed one at a time on the entire set of exogenous variables to obtain calculated values which are then used in the second stage of the technique. Thus, generation of calculated values for endogenous variables beyond the data used in estimating the model involves gathering new data on exogenous variables for a postsample period and calculation of a set of values for the endogenous variables using the estimated parameters of the first stage equations.

In addition, data were gathered on the observed values of the endogenous variables of the model. Postsample calculated values must be compared to these in order to assess the tracking ability of the model beyond the data set upon which it is based.

In general the publications in which this postsample data were found are different from those referenced in Chapter II. Sources for the data used for postsample calculations which are not the same as those formerly given are shown in Table IV; however, in all cases the statistical series used in the postsample period are the same as those used for the sample period.

TABLE IV

SOURCES OF POSTSAMPLE DATA

Variables	Source
P^*_c, P^*_h, Q^*_c, Q^*_h, P^*_{wb}, P^*_{wp}, P^*_{rb}, P^*_{wp}, I_c, I_h, PC, PS	U.S.D.A., "Livestock Market News," Washington, D.C., 1964-1972
CS^*_b, CS^*_p	U.S.D.A., "National Food Situation," Washington, D.C., 1971-1972

Actual and calculated values for selected endogenous variables for a 16 month postsample period are presented in Tables V through XII. Variables pertaining to production (Q^*_b and Q^*_p), per capita consumption (C_b^{*pc} and C_p^{*pc}) and expected change in price ($P_c^{*e\Delta}$ and $P_h^{*e\Delta}$) were not included in these tables. Production variables were assumed to be

TABLE V

ACTUAL VALUES, CALCULATED VALUES AND ERROR IN CALCULATION FOR VARIABLES P_c^* AND P_h^*,[a] JANUARY 1971 THROUGH APRIL 1972

Month	P_c^* Actual Value ($/cwt)	P_c^* Calculated Value	P_c^* Error in Calculation	P_h^* Actual Value ($/cwt)	P_h^* Calculated Value	P_h^* Error in Calculation
1971						
Jan	24.43	28.01	-3.58	13.74	14.56	-0.82
Feb	26.83	26.30	0.53	16.24	12.01	4.23
Mar	26.57	28.44	-1.87	14.25	17.98	-3.73
Apr	26.98	28.63	-1.65	13.45	14.95	-1.50
May	27.14	29.25	-2.11	14.43	17.28	-2.85
Jun	26.69	29.95	-3.26	15.00	15.09	-0.09
Jul	26.60	30.45	-3.85	16.32	20.55	-4.23
Aug	27.12	27.33	-0.21	15.73	17.08	-1.35
Sep	26.77	28.57	-1.80	15.51	12.94	2.57
Oct	26.58	25.40	1.18	16.32	20.65	-4.33
Nov	27.56	22.98	4.58	15.95	18.14	-2.19
Dec	27.92	29.19	-1.27	17.14	18.50	-1.36
1972						
Jan	28.63	31.35	-2.72	20.07	20.32	-0.25
Feb	28.83	29.29	-0.46	20.87	20.41	0.46
Mar	28.08	29.31	-1.23	18.91	21.68	-2.77
Apr	27.63	28.89	-1.26	18.36	19.80	-1.44

[a]Actual values shown for both variables in this table are deflated by the Wholesale Price Index (1957-1959=100).

TABLE VI

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES Q_c^* AND Q_h^*, JANUARY 1971 THROUGH APRIL 1972

	Q_c^*			Q_h^*		
Month	Actual Value (000,000's)	Calculated Value	Error in Calculation	Actual Value (000,000's)	Calculated Value	Error in Calculation
1971						
Jan	3052	2955	97	1966	1989	-23
Feb	2727	2694	32	1645	1878	-233
Mar	3164	3007	157	2116	1962	154
Apr	2984	2883	101	2007	1879	128
May	2955	2543	412	1819	1342	476
Jun	3110	3146	-36	1663	1784	-121
Jul	3137	2805	332	1640	1536	104
Aug	3097	2976	121	1766	1663	103
Sep	3168	3120	48	1887	1639	248
Oct	3067	3225	-158	1854	1565	289
Nov	3025	3212	-187	1989	1665	324
Dec	3010	3146	-136	2001	1952	49
1972						
Jan	3027	3017	10	1671	1804	-133
Feb	2899	2865	34	1598	1725	-127
Mar	3161	3115	46	1992	1889	103
Apr	2877	2815	62	1727	1666	61

TABLE VII

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES ΔCS_b^* AND ΔCS_p^*, JANUARY 1971 THROUGH APRIL 1972

Month	ΔCS_b^* Actual Value (000,000's)	ΔCS_b^* Calculated Value	ΔCS_b^* Error in Calculation	ΔCS_p^* Actual Value (000,000's)	ΔCS_p^* Calculated Value	ΔCS_p^* Error in Calculation
1971						
Jan	8	-42	50	17	-9	26
Feb	-21	-21	0	-9	14	-23
Mar	-3	-53	50	45	-16	61
Apr	-12	-31	19	78	25	53
May	-5	-47	42	31	-78	109
Jun	12	-55	67	-22	-117	95
Jul	15	-22	37	-71	-133	62
Aug	21	3	18	-73	-100	27
Sep	18	-5	23	-23	-65	42
Oct	-4	-22	19	3	-110	113
Nov	-21	-17	-4	15	-64	79
Dec	39	-39	78	3	-56	59
1972						
Jan	-11	-48	37	22	-40	18
Feb	-46	-37	8	-21	1	-22
Mar	-20	-31	11	45	4	41
Apr	15	-16	31	57	33	24

TABLE VIII

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES P^*_{wb} AND P^*_{wp},[a] JANUARY 1971 THROUGH APRIL 1972

	P^*_{wb}			P^*_{wp}		
Month	Actual Value (¢/lb.)	Calculated Value	Error in Calculation	Actual Value (¢/lb.)	Calculated Value	Error in Calculation
1971						
Jan	41.76	45.88	-4.12	38.36	39.47	-1.11
Feb	44.19	43.65	0.54	40.43	34.26	6.17
Mar	43.75	46.72	-2.97	38.87	42.88	-4.01
Apr	44.63	46.09	-1.46	37.19	39.93	-2.74
May	45.50	47.67	-2.17	38.91	42.91	-4.00
Jun	44.24	48.43	-4.19	39.65	41.60	-1.95
Jul	43.99	50.07	-6.08	41.28	43.97	-2.69
Aug	44.95	45.67	-0.72	39.95	40.25	-0.30
Sep	44.19	46.31	-2.12	40.33	41.22	-0.89
Oct	43.35	42.61	0.74	42.83	46.83	-4.00
Nov	45.28	38.41	6.87	41.89	45.54	-3.65
Dec	46.47	47.62	-1.15	42.69	45.17	-2.48
1972						
Jan	47.39	51.29	-3.90	45.54	45.40	0.14
Feb	47.04	47.90	-0.86	47.31	45.15	2.16
Mar	44.98	47.41	-2.43	45.51	48.42	-2.91
Apr	43.96	46.76	-2.80	43.71	45.80	-2.09

[a]Actual values shown for both variables in this table are deflated by the Wholesale Price Index (1957-1959=100).

TABLE IX

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES M_b^* AND M_p^*,[a] JANUARY 1971 THROUGH APRIL 1972

	M_b^*			M_p^*		
Month	Actual Value (¢/lb.)	Calculated Value	Error in Calculation	Actual Value (¢/lb.)	Calculated Value	Error in Calculation
1971						
Jan	17.10	10.57	6.53	15.35	17.11	-1.76
Feb	15.86	12.20	3.66	13.72	19.78	-6.06
Mar	17.71	14.20	1.51	15.59	13.07	2.52
Apr	16.78	15.12	1.66	16.20	15.34	0.86
May	16.07	14.17	1.90	13.82	12.76	1.06
Jun	17.54	9.68	7.86	13.94	13.62	0.32
Jul	17.05	15.31	1.74	13.56	13.60	-0.04
Aug	16.52	16.89	-0.37	14.91	16.40	-1.49
Sep	17.60	18.62	-1.02	14.25	14.51	-0.26
Oct	18.03	23.70	-5.67	12.02	9.43	2.59
Nov	16.75	25.82	-9.07	13.00	11.16	1.84
Dec	16.33	13.87	2.46	12.89	13.32	-0.43
1972						
Jan	16.67	13.77	2.90	12.20	15.57	-3.37
Feb	18.91	15.61	3.30	13.74	17.14	-3.46
Mar	20.91	17.34	3.57	14.01	14.61	-0.60
Apr	19.72	17.76	1.96	14.87	15.87	-1.00

[a] Actual values shown for both variables in this table are deflated by the Wholesale Price Index (1957-1959=100).

TABLE X

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES P^*_{rb} AND P^*_{rp},[a] JANUARY 1971 THROUGH APRIL 1972

Month	P^*_{rb} Actual Value (¢/lb.)	P^*_{rb} Calculated Value	P^*_{rb} Error in Calculation	P^*_{rp} Actual Value (¢/lb.)	P^*_{rp} Calculated Value	P^*_{rp} Error in Calculation
1971						
Jan	71.04	68.67	2.37	49.21	52.83	-3.62
Feb	73.21	67.45	5.76	50.11	49.87	0.24
Mar	72.19	73.37	-1.18	50.18	51.07	-0.89
Apr	74.47	73.47	1.00	49.14	50.16	-1.02
May	74.66	74.03	0.63	48.54	50.29	-1.75
Jun	74.80	69.96	4.84	49.26	50.92	-1.66
Jul	73.94	77.92	-3.98	50.43	51.87	-1.44
Aug	74.44	73.80	0.64	50.42	50.33	0.09
Sep	74.52	77.16	-2.64	49.96	49.42	0.54
Oct	73.86	78.41	-4.55	50.10	49.10	1.00
Nov	74.55	76.77	-2.22	50.07	50.47	-0.40
Dec	75.77	72.97	-2.80	50.91	53.00	-2.09
1972						
Jan	77.80	77.57	0.23	53.24	55.29	-2.05
Feb	80.41	75.53	4.88	56.46	56.36	0.10
Mar	80.30	77.15	3.15	55.06	57.07	-2.01
Apr	77.51	76.78	0.73	54.12	55.65	-1.53

[a]Actual values shown for both variables in this table are deflated by the Consumer Price Index (1957-1959=100).

TABLE XI

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLES C_b^* AND C_p^*, JANUARY 1971 THROUGH APRIL 1972

Month	C_b^* Actual Value (000,000's)	C_b^* Calculated Value	C_b^* Error in Calculation	C_p^* Actual Value (000,000's)	C_p^* Calculated Value	C_p^* Error in Calculation
1971						
Jan	1284	1267	17	1277	1309	-32
Feb	1163	1169	-6	1090	1209	-119
Mar	1328	1296	32	1337	1300	37
Apr	1269	1228	41	1230	1205	25
May	1254	1108	146	1169	951	218
Jun	1299	1363	-64	1114	1281	-167
Jul	1315	1208	107	1143	1122	21
Aug	1289	1273	16	1226	1170	56
Sep	1330	1327	3	1259	1133	126
Oct	1301	1396	-95	1208	1131	77
Nov	1285	1334	-49	1290	1146	144
Dec	1229	1342	-113	1307	1333	-26
1972						
Jan	1283	1291	-8	1121	1214	-93
Feb	1251	1244	7	1073	1122	-49
Mar	1341	1332	9	1272	1238	34
Apr	1205	1202	3	992	1061	-69

TABLE XII

ACTUAL VALUES, CALCULATED VALUES AND ERRORS IN CALCULATION FOR VARIABLE P^*_{rbr};[a] CALCULATED VALUES AND ERRORS IN CALCULATION FOR Q^*_c AND Q^*_h FROM EQUATIONS (1a) AND (2a)

	P^*_{rbr}			Q^*_c		Q^*_h	
Month	Actual Value (¢/lb.)	Calculated Value	Error in Calculation	Calculated Value[b] (000,000's)	Error in Calculation	Calculated Value[b] (000,000's)	Error in Calculation
1971							
Jan	28.93	26.59	2.34	3261	-209	2823	-857
Feb	28.59	26.52	2.07	2837	-110	2431	-786
Mar	29.29	30.50	-1.21	3018	146	2093	23
Apr	29.18	29.58	-0.40	3032	-48	2251	-244
May	28.97	28.01	0.96	3051	-96	1862	-43
Jun	29.94	28.69	1.25	3092	18	2267	-604
Jul	29.94	27.76	2.18	3170	-33	2556	-916
Aug	29.72	27.11	2.61	3137	-40	2278	-512
Sep	29.70	23.07	6.63	3183	-15	1603	284
Oct	28.88	24.30	4.58	3392	-325	1405	449
Nov	28.26	25.07	3.19	3041	-16	1357	632
Dec	28.00	29.50	-1.50	3130	-120	2389	-388
1972							
Jan	28.33	28.36	-0.03	3375	-348	2691	-1020
Feb	28.89	28.83	-0.06	2904	-5	2310	-712
Mar	29.06	31.90	-2.84	3087	73	2046	-54
Apr	28.86	30.40	-1.54	3154	-277	2133	-406

[a]Actual values shown for P^*_{rbr} in this table are deflated by the Consumer Price Index (1957-1959=100).

[b]For actual values see Table V, page 93.

constant multiples of slaughter, thus values for Q_b^* and Q_p^* are merely constant multiples of Q_c^* and Q_h^*, respectively. Similarly, per capita consumption variables (C_b^{*pc} and C_p^{*pc}) are nearly constant multiples of their gross consumption counterparts (C_b^* and C_p^*). It was not felt that expected change in prices ($P_c^{*e\Delta}$ and $P_h^{*e\Delta}$) were of central importance to the model, therefore they were omitted from this portion of the analysis.

Calculated values for quantities of cattle and hogs marketed which appear in Table XII were obtained using the coefficients of equations (1a) and (2a). These will be compared to analogous values given by the reduced form equation to determine the tracking ability of these inventory equations relative to equations which include all predetermined variables in the model.

Two objective criteria will be used in assessing the correctness of these calculated values. The first of these, the inequality coefficient, measures how closely calculated values approximate actual magnitudes while a second, number of correct directions of change, gives an indication of how often the calculations change in the same direction as does the actual data (Hee, 1966; Theil, 1966).

The first of these two measures, the inequality coefficient, is defined as the square root of:

$$U^2 = \frac{\sum_{t=1}^{T} (P_t - A_t)^2}{\sum_{t=1}^{T} A_t^2}$$

where

P_t = calculated change for period t,

A_t = actual change for period t, and

T = total number of predictions.

This index has the property of being equal to zero if the calculated values are exactly correct. It is equal to or greater than one as the calculations perform as well as or worse than a no change extrapolation.

Where this index is used for an equation in which levels (as opposed to changes) in endogenous variables are involved, calculated change for period t (P_t) becomes the calculated level for period t minus the actual level for period t-1. Similarly, the actual change for period t (A_t) becomes the actual level for period t minus the actual value for period t-1.

Thus, the computational formula used for this statistic when the level of a variable (Y) is involved in the square root of:

$$U^2 = \frac{\sum_{t=1}^{T} (Y_t^p - Y_t^a)^2}{\sum_{t=1}^{T} (Y_t^a - Y_{t-1}^a)^2}$$

where

Y_t^p = calculated value for Y for period t,

Y_t^a = actual value of Y for period t,

Y_{t-1}^a = actual value of Y for period t-1, and

T = total number of predictions.

Computed values for U are presented in Table XIII for three periods of prediction: (a) the 16 month period from January 1971 through April 1972, (b) the 4 month period from January 1972 through April 1972, and (c) the 12 month period from January 1971 through December 1971.

It is obvious that judged from the U criteria the model's reduced from equations do not track the data exceptionally well over the 16 month period. In particular, the calculated values for these equations over this period were superior to a no change extrapolation for only four variables: Q_c^*, Q_h^*, C_b^*, and C_p^*.

However, for the 4 month subperiod this statistic shows that the calculated values of the model are superior to no change extrapolation for eight variables: P_h^*, Q_c^*, Q_h^*, ΔCS_b^*, ΔCS_p^*, P_{rp}^*, C_b^*, and C_p^*. In fact, with the exceptions of P_c^*, P_{wp}^*, and M_p^*, when the values for U are compared between the two subperiods they are lower during the 4 month span.

It is not surprising then that the calculated values performed very poorly for the 12 month subperiod. For only one variable, consumption of pork, was U less than 1.0 for January 1971 through December 1971.

These results might be an indication that the year of 1971 was "unusual" compared to the 84 month sample period and the 4 month subperiod. Although it is beyond the scope of this study, it is suggested that further research into these results might find that the economic controls applied by the Federal Government in August 1971 (Newsweek, 1971) could have been at least partially responsible for the increased power of prediction during the 4 month subperiod.

TABLE XIII

VALUES OF U FOR SELECTED ENDOGENOUS VARIABLES—JANUARY 1971 THROUGH APRIL 1972; JANUARY 1972 THROUGH APRIL 1972; AND JANUARY 1971 THROUGH DECEMBER 1971

Endogenous Variable	U for January 1971-April 1972	U for January 1972-April 1972	U for January 1971-December 1971
P_c^*	2.78	2.86	2.77
P_h^*	1.91	0.87	2.38
Q_c^*	0.89	0.21	1.06
Q_h^*	0.90	0.38	1.15
ΔCS_b^*	1.85	0.94	2.31
ΔCS_p^*	1.53	0.99	1.65
P_{wb}^*	2.19	1.84	2.20
P_{wp}^*	1.71	2.65	2.01
M_b^*	3.11	1.64	3.59
M_p^*	1.77	2.65	1.59
P_{rb}^*	2.11	1.35	2.75
P_{rp}^*	1.28	0.75	2.36
C_b^*	0.87	0.08	1.08
C_p^*	0.73	0.33	0.99
P_{rbr}^*	5.58	4.61	5.73
Q_c^{*} [a]	0.87	1.10	0.74
Q_h^{*} [b]	2.73	2.25	2.80

[a]U computed from predictions given by equation (1a).

[b]U computed from predictions given by equation (2a).

Values for Q_c^* calculated from equation (1a) were superior to those arrived at by a no change extrapolation during the 16 and 12 month periods. In fact, this equation yielded calculated values which were, in the sense of a lower value for U, superior to those of the reduced form equations for this variable during these two periods.

On the other hand, calculated values for Q_h^* from equation (2a) were inferior to both a no change extrapolation and those of the reduced form for all three periods. These results might imply that knowledge of factors other than published inventory levels is necessary in order to make reasonably accurate forecasts of monthly hog marketings. The fact that the reduced form equation for this variable, which included a number of variables other than hog inventory, yielded results with U values of less than 1.0 for the 16 and 4 month periods tends to reinforce this suggestion.

For the second of the two measures of accuracy, number of correct directions of change, a calculated value is considered correct if the observed direction of change for a particular variable agrees with the direction of change of the calculated values for that same variable. The cumulative binomial probability function is then used to evaluate the likelihood that an equal or greater number of correct changes could have occurred by chance alone. Use of this probability function is based upon the assumption that, a priori, there is by chance alone an equal probability for success or failure of a given change.

This criteria will be used in two somewhat different contexts, namely, to evaluate month to month calculated values for the entire

16 month period, the 4 and 12 month subperiods, and finally, to compare actual as opposed to calculated changes between February 1971 and February 1972.

Month to month calculated values given by the models evaluated by this criteria are shown in Table XIV.

For the 16 month period the model's reduced from equations give a correct direction of change for only 141 or 59 percent of a possible 240 occurrences. During the 4 month subperiod the direction of change was correct in 44 or 73 percent of a possible 60 occurrences. Thus, again, the model is somewhat superior in tracking during the 4 month subperiod as compared to the 16 month period, although this result could be due to the shortness of the 4 month period.

Calculated values generated by both Equation (1a) and (2a) are shown to be somewhat inferior to those of the reduced form equations for the 16 month period for tracking changes in direction. Equation (1a) seems to be by far the better of the two "inventory alone" equations judged on this criteria.

Actual and calculated changes in the selected endogenous variables between February 1971 and February 1972 are shown in Table XV. This particular month is highlighted here as retail beef and pork prices reached historical levels which elicited a considerable and vocal response from consumers during February 1972.

The purpose here is to determine if the model tracks increases in these prices. Should this be the case then it can be said that these increases were, to a degree, the result of workings within a system as

TABLE XIV

NUMBER OF CORRECT DIRECTIONS OF CHANGE AND PROBABILITY OF AN EQUAL OR GREATER NUMBER OF CORRECT DIRECTIONS OF CHANGE OCCURRING BY CHANCE ALONE, SELECTED ENDOGENOUS VARIABLES, JANUARY 1971 THROUGH APRIL 1972 AND JANUARY 1972 THROUGH APRIL 1972

Endogenous Variable	Correct Directions of Change January 1971-April 1972[a]	Probability[b]	Correct Directions of Change January 1971-April 1972[c]	Probability[b]
P_c^*	7	0.72	2	0.69
P_h^*	12	0.04	3	0.31
Q_c^*	12	0.04	3	0.31
Q_h^*	13	0.01	4	0.06
ΔCS_b^*	8	0.60	3	0.31
ΔCS_p^*	9	0.40	4	0.06
P_{wb}^*	8	0.60	4	0.06
P_{wp}^*	12	0.04	2	0.69
M_b^*	8	0.60	2	0.69
M_p^*	11	0.11	2	0.69
P_{rb}^*	5	0.96	2	0.69

TABLE XIV (continued)

Endogenous Variable	Correct Directions of Change January 1971-April 1972[a]	Probability[b]	Correct Directions of Change January 1971-April 1972[c]	Probability[b]
P^*_{rp}	10	0.23	3	0.31
C^*_b	11	0.11	3	0.31
C^*_p	14	0.002	4	0.06
P^*_{rbr}	11	0.11	3	0.31
Q^*_c [d]	9	0.40	3	0.31
Q^*_h [e]	5	0.96	1	0.94

[a]Number of correct directions of change out of a possible 16.

[b]Probability of an equal or greater number of correct directions of change by chance alone.

[c]Number of correct directions of change out of a possible 4.

[d]Calculated values based on Equation (1a).

[e]Calculated values based on Equation (2a).

TABLE XV

ACTUAL VALUES, ACTUAL CHANGE IN VALUES, AND CALCULATED CHANGE IN VALUES FOR SELECTED ENDOGENOUS VARIABLES, FEBRUARY 1971 AND FEBRUARY 1972

Variable	Units	Actual Value February 1971	Actual Value February 1972	Calculated Value February 1972	Actual Change	Calculated Change[c]
P_c^{*} [a]	\$/cwt	26.83	28.83	29.29	2.00	2.46
P_h^{*} [a]	\$/cwt	16.24	20.87	20.41	4.63	4.17
Q_c^{*}	000,000's lbs.	2727	2899	2865	172	138
Q_h^{*}	000,000's lbs.	1645	1598	1725	-47	80
ΔCS_b^{*}	000,000's lbs.	-21	-46	-37	-25	-16
ΔCS_p^{*}	000,000's lbs.	-9	-21	1	-12	10
P_{wb}^{*} [a]	¢/lb.	44.19	47.04	47.90	2.85	3.71
P_{wp}^{*} [a]	¢/lb.	40.43	47.31	45.15	6.88	4.72
M_b^{*} [a]	¢/lb.	15.86	18.21	15.61	2.35	-0.25
M_p^{*} [a]	¢/lb.	13.72	13.74	17.14	0.02	3.42
P_{rb}^{*} [b]	¢/lb.	73.21	80.41	75.53	7.20	2.32
P_{rp}^{*} [b]	¢/lb.	50.11	56.46	56.36	6.35	6.25

TABLE XV (continued)

Variable	Units	Actual Value February 1971	Actual Value February 1972	Calculated Value February 1972	Actual Change	Calculated Change[c]
C_b^*	000,000's lbs.	1163	1251	1244	88	81
C_p^*	000,000's lbs.	1090	1073	1122	-17	32
$P_{rbr}^{*\,b}$	¢/lb.	28.59	28.89	28.83	0.30	0.24

[a]Values shown are deflated by the Wholesale Price Index (1957-1959=100).

[b]Values shown are deflated by the Consumer Price Index (1957-1959=100).

[c]Equals calculated value, February 1972, minus actual value, February 1971.

estimated by the model during the period 1964-1970. On the other hand, if the model fails, then it may be true that subsequent to the sample period (1964-1970) changes have taken place in the structure of the beef-pork marketing system.

For eleven of the fifteen endogenous variables considered in Table XV the model showed a correct direction of change. All slaughter animal, wholesale, and retail prices increased between the two years, a fact which the model tracks without error. To this extent, price increases for beef and pork between the two months were the result of a structure which existed during the 1964-1970 sample period.

Upon closer examination, however, this table (Table XV) contains some evidence that the retail price of beef was not behaving in a manner suggested by the first stage equation for this variable. Although the model did correctly show that the level of this variable would rise, it understated the actual increase of 7.20 cents per pound by a factor of three.

CHAPTER IV

SUMMARY AND CONCLUSIONS

I. SUMMARY

The principal aims of this study were the specification, statistical estimation and evaluation of a simultaneous monthly model of the U. S. beef and pork sector.

A secondary, but not unimportant, objective was using the estimated model to analyze the price rises which occurred in retail beef and pork prices during the first four months of 1972. Lastly, the usefulness of recently begun U.S.D.A. data series on cattle and hog inventories which were utilized in this study were tested with respect to ability in the prediction of marketings.

Variables normalized on in the behavioral equations were quantity of cattle marketed, quantity of hogs marketed, packer level price of cattle, packer level price of hogs, change in cold storage of beef, change in cold storage of pork, wholesale to retail marketing margin for beef, wholesale to retail marketing margin for pork, per capita consumption of beef, per capita consumption of pork, and retail price of broilers.

Data for the model came entirely from secondary sources, mainly U.S.D.A. statistical series. The data period included all months from January 1964 through December 1970. Additional data from these same series were gathered for use in a postsample period beyond December 1970.

Two stage least squares was used to obtain estimates of the parameters of the model.

The most important variables in explaining variations in monthly quantities marketed of cattle and hogs were inventory levels of cattle and hogs, respectively. Quarterly data were used for both inventory variables with slope change and intercept dummy variables to account for impacts of inventories in the months between quarterly reports. Cattle and hog prices, when formulated as expected change variables, made small contributions to explanation of variations in quantities marketed when the effects of inventories had been taken into account.

Variables important in the explanation of deflated packer level prices of cattle and hogs included respective quantities and deflated wholesale prices. In addition, deflated packer wage rates and number of workdays were important in explanation of both prices. To account for changes in the composition of slaughter cattle and hogs, percent of slaughter quantities of the two meats consisting of cows and sows, respectively, were included. The intercepts of both functions varied somewhat among months. Lastly, change in cold storage of the respective meats was included in these equations, however, both estimated coefficients were statistically insignificant.

Factors which were important in explaining variations in changes in cold storage of beef and pork included respective deflated wholesale and expected change price variables, production levels and beginning inventories of cold storage. Both functions displayed variation in intercepts among months.

Deflated retail wages and respective quantities consumed exerted positive influences on wholesale to retail marketing margins with that for beef being the most responsive to wages. The two margins behaved differently with respect to deflated wholesale prices with that for beef having a significant negative sign for this variable while for the pork margin the effect was positive, small, and statistically insignificant.

Per capita quantity demanded of beef and pork was responsive to deflated retail prices of beef, pork, and broilers and deflated per capita income. In addition, both functions displayed a degree of variation in intercepts among months. The estimated retail demand function for beef indicated that beef and pork are weak substitutes while the same equation for pork indicated an insignificant complementary relationship.

A retail demand function for broilers was estimated under the assumption that broiler consumption is predetermined. Therefore, the normalized variable is, in this case, deflated retail price. It was found that consumption extended a negative influence over the dependent variable while the coefficients for deflated retail beef and pork prices were positive and significant, indicating that both meats are substitutes for broilers. In contrast to the retail demand functions for beef and pork, a negative coefficient for income was estimated for this equation. Deflated retail broiler price exhibited a degree of fluctuation with respect to monthly intercept dummy variables.

It was found that at the retail level price elasticities for beef and pork were less than one, while an inverse of price flexibility indicated that demand for broilers was price elastic in nature. Income elasticities for beef and pork were positive and less than one.

First stage equations of the two stage least squares technique were used to calculate values for selected endogenous variables for the period January 1971 through April 1972. When compared to the actual values of the endogenous variables the calculated were somewhat disappointing in that in most cases a no change extrapolation proved to be superior in terms of closeness of fit to actual values. On the other hand, the model did perform fairly well for one four month subperiod, January through April 1972. This period was of special interest as beef and pork prices reached historically high levels during these months.

II. CONCLUSIONS

It is believed that, given the estimated model, the following conclusions are warranted with respect to the monthly structure of the U. S. beef-pork marketing sector:

1. The primary variables which influence the monthly pattern of marketings of cattle and hogs are respective inventories of the two variables. Thus, the concept of monthly quantities marketed as endogenous variables is open to question.

2. Recently begun U.S.D.A. quarterly estimates of cattle and hog inventories appear to perform satisfactorily in a model of the type developed herein in the sense of explaining a large proportion of the

variation in monthly cattle and hog marketings. However, in the case of hogs, calculations of monthly marketings based on inventory levels alone were not, based on the criteria utilized, accurate enough to be useful in postsample tracking of the path of monthly hog slaughter.

3. It would appear that meat packers do not consider cold storage to be important in pricing cattle and hogs.

4. Based on the estimated coefficients for wholesale price in the packer demand and margin equations it would appear that the meat marketing system transmits price changes among the three levels considered.

5. The demand for beef and pork at the retail level is price and income inelastic.

6. From a summary table of elasticities estimated in past studies it would appear that beef is becoming increasingly price and income inelastic, and income elasticity has become positive for pork. This conclusion is highly tentative, as the coefficients upon which these trends are based were estimated using a variety of different techniques and assumptions.

7. Retail price rises for beef and pork which took place in early 1972 were, to a degree, tracked by the reduced form equations of the model. However, the model underpredicted the price rise for beef by a substantial amount, indicating that some changes may have occurred in the estimated structure of the beef sector.

III. SUGGESTIONS FOR FUTURE RESEARCH

The model developed in this study leaves open to question many aspects of the beef-pork marketing system. Producer response patterns to changes in short term prices is certainly an area which needs further investigation, as does the relationship of cold storage stocks to packer pricing decisions. At the retail level one omitted variable which may be relevant is the Food Stamp program. It would be interesting to know the impact of the program on retail purchases of beef and pork, *ceteris paribus*.

The model developed herein certainly leaves much to be desired in the area of tracking postsample data, thus implying that it would be a poor forecasting tool. Much work remains to be done in the area of developing models which will predict future behavior of an economic system.

Lastly, if U.S.D.A. initiates publication of monthly estimates of cattle and hog inventories more exact inquiries could be made into the relationships between these variables and monthly levels of marketings.

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APPENDIX

TABLE XVI

ARITHMETIC MEANS, STANDARD DEVIATIONS, AND RANGES FOR THE ENDOGENOUS VARIABLES OF THE MODEL, 1964-1970[a]

Variable	Units	Arithmetic Mean	Standard Deviation	Range
Q_c^*	000,000's pounds	2856.63	203.32	1127.00
Q_h^*	000,000's pounds	1622.13	191.26	925.00
$P_c^{*e\Delta}$	$/hundredweight	-0.06	0.40	3.09
$P_h^{*e\Delta}$	$/hundredweight	-0.04	0.62	3.29
P_c^*	$/hundredweight	24.67	1.67	19.97
P_h^*	$/hundredweight	19.34	3.31	16.66
ΔCS_b^*	000,000's pounds	0.84	17.64	75.51
ΔCS_p^*	000,000's pounds	1.02	39.62	174.93
P_{wb}^*	¢/pound	40.32	2.43	14.00
P_{wp}^*	¢/pound	46.22	4.91	20.92
Q_b^*	000,000's pounds	1667.60	131.62	796.17
Q_p^*	000,000's pounds	1139.76	134.36	648.15
M_b^*	¢/pound	16.33	1.66	7.17
M_p^*	¢/pound	13.48	1.43	7.33

TABLE XVI (continued)

Variable	Units	Arithmetic Mean	Standard Deviation	Range
C^*_b	000,000's pounds	1181.74	90.69	461.62
C^*_p	000,000's pounds	1063.58	105.55	549.35
C^{*pc}_b	pounds	5.94	0.37	1.96
C^{*pc}_p	pounds	5.35	0.50	2.47
P^*_{rb}	¢/pound	51.40	1.66	8.46
P^*_{rp}	¢/pound	54.21	4.86	21.13
P^*_{rbr}	¢/pound	33.68	2.28	11.30

[a]Price variables are deflated as shown in Table I, page 46; quantity variables are on a per month basis.

TABLE XVII

ARITHMETIC MEANS, STANDARD DEVIATIONS, AND RANGES FOR THE EXOGENOUS VARIABLES OF THE MODEL, 1964-1970[a]

Variable	Units	Arithmetic Mean	Standard Deviation	Range
I_c	000,000 head	9.56	1.45	5.70
$I_{h,60-119}$	000,000 head	9.14	1.53	5.61
$I_{h,120-179}$	000,000 head	7.64	1.44	4.95
$I_{h,180-219}$	000,000 head	4.38	0.84	2.91
P_f	$/bushel	1.17	0.11	0.42
W_p	$/hour	3.08	0.19	0.67
WD	days	22.95	0.84	3.1
PC	percent	20.67	3.10	13.9
PS	percent	7.28	1.99	9.1
$CS_{b(t-1)}$	000,000's pounds	266.90	46.52	211.53
$CS_{p(t-1)}$	000,000's pounds	258.67	75.73	347.28
W_r	$/hour	1.92	0.06	0.22
I^{pc}	dollars	223.51	0.02	60.00
C_{br}^{pc}	pounds	2.62	0.34	1.51

[a]Price, wage, and income variables are deflated as shown in Table I, page 46.

VITA

Thomas Earl Elam was born June 9, 1946, in Winston Salem, North Carolina. He attended the public schools of Rocky Mount, North Carolina, and Jackson, Tennessee. He was graduated from Jackson High School in June of 1964. In September of 1964 he entered Union University, Jackson, Tennessee, and in August 1969 received the B.S. degree from that institution. In September 1969 he entered the Graduate School of the University of Tennessee at Knoxville, majoring in agricultural economics. He was granted the M.S. degree from that institution in March 1971 and the Ph.D. degree in March 1973. In August 1972 he took a position of Assistant Professor of Economics at Northern Kentucky State College, Highland Heights, Kentucky. He is married to the former Sandra Gayle Britt of Jackson, Tennessee, and has two daughters.