Economic factors influencing steer-heifer price differences in the livestock-meat market
by Robert William Schultz

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
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Abstract:
Steer and heifer price differences fluctuate at all levels of the market. Part of the difference is biological and reflects preferences of cattle feeders and packers. A rational distributed lag model of quarterly prices for steers, heifers, and the difference is estimated for the wholesale, slaughter, and feeder markets to identify and evaluate the economic factors creating this phenomenon. The rational lags are estimated using a nonlinear least squares algorithm, incorporating the specification of nonstochastic difference equations. The purpose is to divorce the disturbance processes from the systematic portion of the difference equations.

Factors found to be significant in determining individual steer and heifer prices are included in the price difference equations. Statistical tests then determine which variables are significant in influencing the price difference.

Partial derivatives and price flexibilities are calculated to estimate short- and long-run adjustments of prices in response to changes in exogenous variables. Results indicate, given quality, that the steer-heifer carcass price difference is influenced by the supply of carcasses and random factors. However, the random factors dominate. The slaughter price difference is affected by steer carcass price. Feeder cattle price is evaluated for light and heavy weight categories. The light feeder steer-heifer price difference is affected by slaughter steer price and quantity of steers and quantity of heifers on feed. The heavy feeder price difference is affected by the same variables plus corn price, an important cost of gain factor.

ECONOMIC FACTORS INFLUENCING STEER-HEIFER PRICE

DIFFERENCES IN THE LIVESTOCK-MEAT MARKET

by

ROBERT WILLIAM SCHULTZ

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

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CHAPTER 1

INTRODUCTION

Introduction and General Market Structure

The United States agricultural sector is highly integrated with national and international markets. This has led to a certain degree of vulnerability as economic conditions in the national and international scenes have varied. Though the international market has a greater direct impact on grain producers, indirectly cattle producers are also affected. As a result, beef livestock producers and processors have had to consider ways to add flexibility to their marketing strategies and to improve their ability to forecast prices and production.

The production of beef cattle and meat can be separated into different market levels or production stages: (1) cow-calf production and yearling production; (2) fed and nonfed slaughter cattle production; and (3) wholesale or carcass and fabricated beef production. Those involved in the production of cattle are commonly called cow-calf and cow-yearling producers. These producers maintain a breeding herd from which they generally produce 300-500 pound feeder calves or, through retained ownership, 600-800 pound yearling cattle. Usually these cattle, less a certain percentage of heifers retained for replacement purposes, are marketed to either feedlots or directly to slaughter. The marketing process can be through local auctions, terminal markets, or, as the trend in recent years shows, direct ranch sales to feedlots. Once in the feedlot, calves and yearlings are fed high-energy grain rations to meet certain quality and yield grade standards desired by packers. These cattle are typically referred to as "fed" beef. Alternatively, calves can be retained by the cow-calf producer or sold to stocker operators for yearling operations where they are usually placed on a roughage (range or hay) diet. Those that are marketed directly to slaughter and processing plants are typically referred to as "non-fed" cattle.

The slaughtering and processing industry has undergone considerable change over the decades. Historically, slaughter plants killed cattle, marketed the by-products, railed dressed beef into coolers and then sold the carcasses to wholesalers and retailers. The boning, breaking, and processing of carcases was done by the wholesalers and retailers. More recently there has been a move toward more vertical integration of the slaughter and fabrication functions at the packing plant. The need to adjust to higher interest rates, labor costs, obsolescence, and shifts in livestock producing areas has encouraged such efficiency. The product of large scale breaking and boning of the carcasses at the packing plant is given the term boxed beef (fabrication of carcasses into primal and subprimal cuts, boxed and frozen for transport to retailers).

Statement of the Problem

Commercial cow-calf producers, feedlot operators, and beef slaughtering firms all face at least one common marketing decision; the optimum strategy of buying inputs and selling outputs in a most economically efficient manner. The purchase price of steers and heifers offered by cattle feeders influences a rancher's production returns, and the sale price of fed steers and heifers (purchase price offered by packers) affects a cattle feeder's finishing returns. The wholesale prices of steer and heifer carcasses and boxed beef significantly impact packer slaughter margins.

Historically, the price per pound of steers has been consistently higher than the price per pound of heifers at all three market levels. The reason for a generally higher price of steers over heifers can be attributed to physiological and growth factors (Boggs and Merkel 1979). Heifers, when placed on a high concentrate ration, will mature earlier but at a lighter live weight than steers on the same feed ration. At maturity heifers have a lower lean-to-fat ratio than steers, i.e., dressed out heifers will have a greater proportion of their weight as fat compared to steers. Since fat is less dense than muscle tissue, the average weight of heifer carcasses is usually less than that of steers. During the growth and adult stage of a heifer's life, a portion of the feed intake is utilized for reproductive development, menstruation and pregnancy requirements. Although these factors may not always affect rates of gain, they do result in lower dressing percentages and additional costs when faced with either preventing pregnancy or calving heifers in feedlots (Riley 1983). Given these factors, cattle feeders have a relatively higher demand for steers, and therefore steers are priced higher per unit of weight than heifers, or analogously, a discounted value is placed on heifers.

What has also been the case, however, is that the difference between steer and heifer prices has shown substantial fluctuation, varying from six cents per pound to 14 cents per pound. As discussed above, at least part of the spread can be accounted for by physiological and growth factors, but they are more likely fixed components of the difference. So the question involves whether economic and other technical factors account for the variation or whether it is more random in nature.

Objectives

The objective of this project is to identify and evaluate the economic factors that influence quarterly steer and heifer price differences at the feeder level, slaughter level, and wholesale or carcass level. Inclusively, an econometric model is developed which specifies the individual behavior of structural steer and heifer prices at each of these levels. The estimated parameters of the conditional probability distributions are used to derive the distributed lag patterns of the endogenous steer and heifer price variables. Finally, the above model formulation is used to construct direct estimation of the price differences, and to analyze the distributed lag pattern of their variance.

Procedures

The hypothesis is that the behavior of quarterly prices is described by rational distributed lags. Economic theory, knowledge of the industry, and previous research contribute to the specification of the model. A nonlinear least squares algorithm incorporating nonstochastic difference equations and serial correlation in the error structure is used to estimate the structural parameters. The structural parameter estimates are then utilized, through partial derivatives, to explain the time effects of the systematic predetermined variables on the endogenous price variables. The estimated structure of steer and heifer prices and their distributed lags provide information for estimating the dynamic behavior of the difference between steer and heifer prices.

Literature Review

Few publications exist that encompass the entire spectrum of price premiums and discounts from the feeding through processing levels. However, several articles about premiums and discounts between steer calves and yearlings and feeder cattle price differences have been published.

A study by Buccola and Jessee (1979) investigated sources of feeder price differentials by sex and analyzed variations in the differentials across time and space dimensions. They state that the feeder sex price differential is a function of differences in backgrounding costs, expected future feeder prices, slaughter prices, feeding costs, and current feedlot inventories. Statistical results showed the annual average grower price of all hay, the price difference between fall Choice 1100-1300 pound steers and fall Choice 900-1100 pound heifers, and annual average grower price of corn had correct signs and were highly significant. The influence of slaughter price differentials on feeder price differentials was minor. Results also showed that a strong affect on sex price differences occurred from preferences of feeding regions for feeding one sex rather than the other. Finally, regional variations in feeder steer-heifer price spreads is mostly explained by differences among regions in slaughter steer-heifer price differentials and in the desired proportion of steers to total cattle on feed.

Work by Buccola (1980) showed that break-even analysis can be used successfully to interpret market price differentials between different lots of feeder cattle. Results indicated that the same variables that affect general feeder price levels also affect price differentials between different classes of feeder cattle. More specifically, feeder cattle price-weight slopes were influenced by expected slaughter cattle prices, feed prices, soil moisture conditions, and inventory adjustments.

Marsh (1983b) presented a partial adjustment process where monthly differences between the price of 400-500 pound steer calves and the price of 600-700 pound yearling steers are affected by expected cost of gain and expected slaughter price. The variation in their difference was significantly determined by length of run.

In Kansas a study was done by Lambert, Corah, and Grunewald (1981) that was designed to determine management and marketing factors affecting the price of calves and yearlings of both gender. While the main emphasis was on the price difference resulting from different weight categories, the results also show discounted values of steers and heifers emanating from effects of health, condition, frame, and grade. Examination of the results show that discounts on steers were greater than that of heifers when the above traits deviated from their respective best levels or qualities.

While all of these studies examine price differences in one form or another, the analyses are restricted to the feeder level. By incorporating a multi market system in the cattle industry, new information could be discovered that sheds further light on their dynamic interrelationships.

CHAPTER 2

THEORETICAL APPLICATIONS IN THE CATTLE INDUSTRY

This section focuses on concepts that are used in formulating a model that explains steer-heifer price differences. Included are (1) distributed lags, (2) econometrics, (3) recursive systems, and (4) pricing mechanisms. The following discussion circumvents the elementary aspects of market supply and demand theory under the assumption that this is already understood.

Distributed Lags

When reference is made to the dynamics of demand theory, two ways of viewing it are; (1) changes in demand which are associated with changes in income, population, or other variables that shift the demand schedule over time, and (2) lags in adjustment. In particular, lags in adjustment result from the inability to make quantity adjustments instantaneously whether it be due to imperfect knowledge, the nature of the commodity, or time required to make changes (Tomek and Robinson 1981). This latter notion of lags in adjustment leads into the concept of distributed lags. That is, for some demand functions the "cause" and "effect" nature of the independent and dependent variables (e.g., price and quantity changes) is likely to be spread over time rather than occurring instantaneously.

While distributed lags appear to be a simple idea on the surface, how the path of adjustment is generated can be complicated. Distributed lag models are usually characterized by either finite or infinte lag structures, but defining the end of the adjustment process makes application of a finite distributed lag empirically difficult. Defining the end of the adjustment process is especially difficult in agricultural applications since numerous biological and economic forces influence any given system. As a result the following discussion is limited to the concept of infinite lags. The distributed lag processes presented are the Koyck geometric lag, the Pascal lag, and the Jorgenson rational lag since all are applicable to the steer-heifer price premium problem.

The Koyck lag represents a declining geometric weight structure on past levels of the relevant independent variable(s) (Wonnacott and Wonnacott 1979). In its infinite form the model is specified as

$$Q_t = a + b_1 P_t + b_2 P_{t-1} + b_3 P_{t-2} + b_4 P_{t-3} + \ldots e_t \qquad (1)$$

Statistical estimation problems with an infinite lag form are: (1) the large number of parameters make it very costly in terms of degrees of freedom, and (2) multicollinearity can occur between the lagged variables. Equation 1 can be estimated by performing a Koyck transformation, which transforms it into a three parameter function

$$Q_t = a(1-\lambda) + b_1 P_t + \lambda Q_{t-1} + e_t - \lambda e_{t-1} \qquad (2)$$

with the value of λ, the difference equation parameter, dictating the rate of decay (i.e., a high value for λ would indicate a slow rate of decay and vice versa for a low value of λ). Examples are provided in Figure 1.

In the Pascal lag distribution the weights may initially increase to some peak and then decline throughout (Kmenta 1971). The Pascal lag is a two parameter density function and is specified as

$$Q_t = bW(L)P_t + e_t \qquad (3)$$

where W(L) is the power series function in the lag operator L, so that the weight structure is defined as

$$W(L) = \frac{(1-\lambda)^r}{(1-\lambda L)^r} . \qquad (4)$$

The value of r determines the order of the difference equation and the moving average error process, and the value of λ again determines the rate of decay. All roots are real, posi-

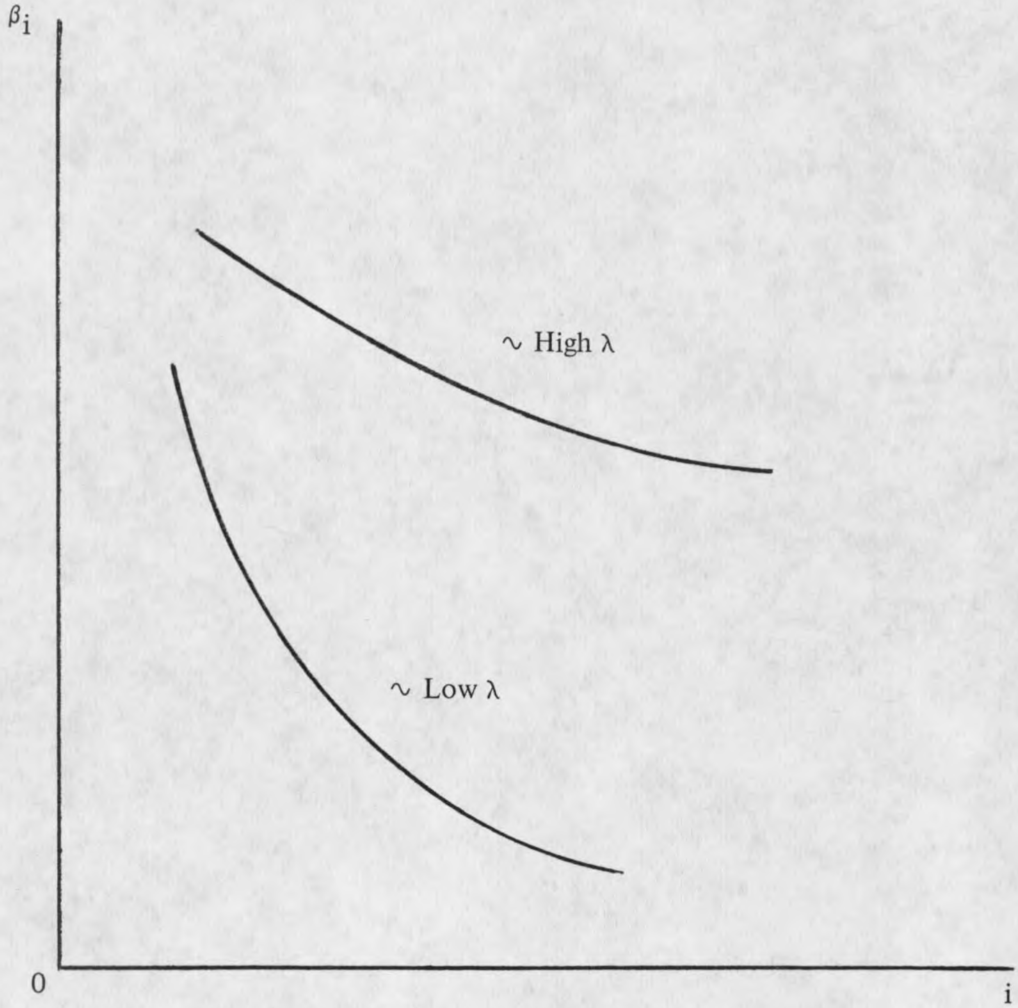

Figure 1. Koyck geometric lag.

tive, and equal. In the special case of r=1 a geometric lag results. As r increases by one, the peak impact of the independent variable shifts back by one period. The shape of the Pascal distribution corresponding to different values of r are shown in Figure 2. If the value of r cannot be determined a priori, estimation of r through maximum likelihood procedures is involved and may not be practical.

Another weight structure relevant to dynamic models is the rational lag given by Jorgenson (1966). This type of model is given as

$$Q_t = bW(L)P_t + e_t \qquad (5)$$

where

$$W(L) = \frac{A(L)}{\beta(L)} . \qquad (6)$$

In the weight structure of (6), A(L) is a polynomial of order m in the lag operator L specific to the dependent variable. Usually $m \leq n$. In this specification the order of the denominator sets the order of the difference equation as well as the order of the moving average disturbance process. The roots of the function may be either real of imaginary depending upon the values of the coefficients of the lagged dependent variables.

Jorgenson (1966) showed that any arbitrary lag function can be approximated to any desired degree of accuracy by a rational distributed lag function when m and n are of sufficient magnitude. This implies that the class of rational distributed lags may include the geometric as well as Pascal lag structure.

Several potential problems exist with regard to rational lags. First, the rational lag scheme may not always approximate the arbitrary lag distribution in a relevant or meaningful sense. That is, the sum of the lag coefficients of the lagged dependent variable may show an explosive or diverging pattern. Second, it is difficult to specify a priori the orders of m and n of the polynomial functions. Oftentimes they are empirically determined. Finally, and likely most important, is the problem of model misspecification which stems

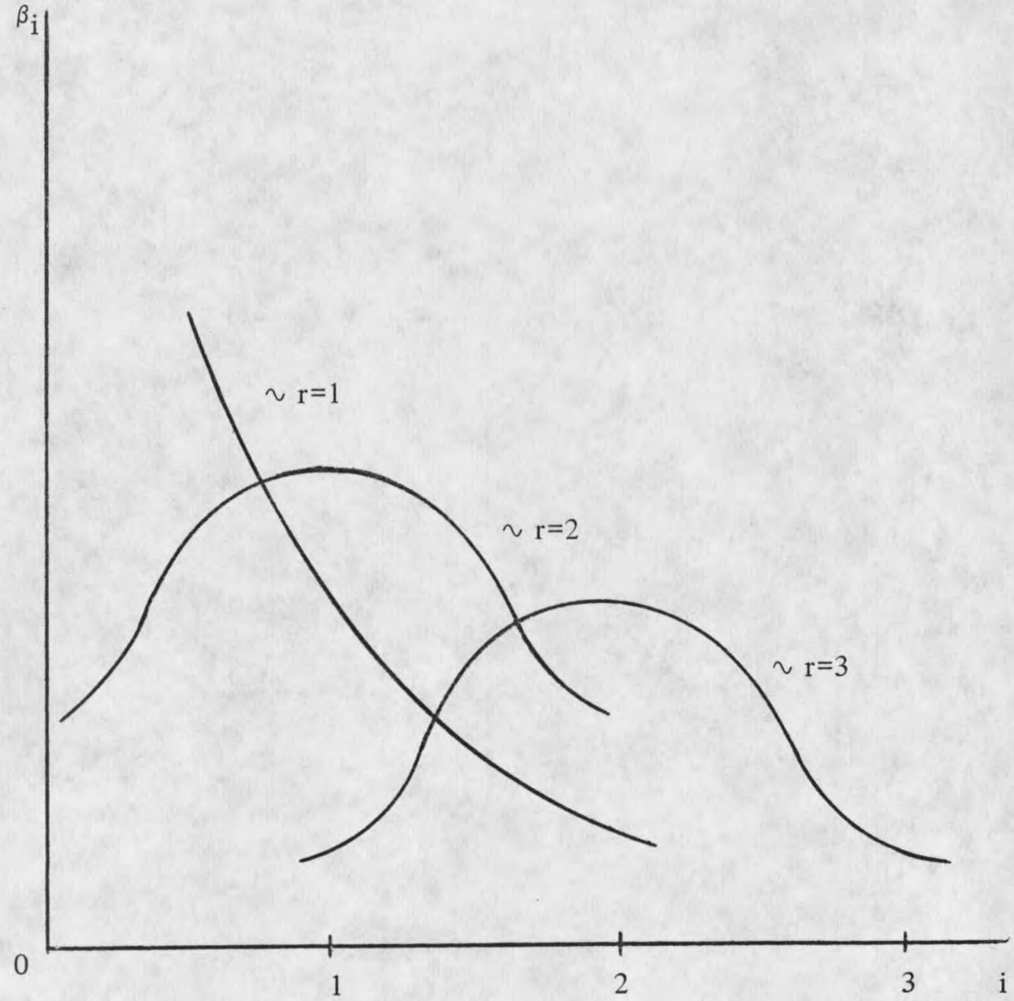

Figure 2. Pascal distributions.

from the rational lag structure being reduced to an nth order difference equation with an nth order moving average error structure. Ordinary least squares regression analysis yields biased and inconsistent parameter estimates because of the correlation between the lagged dependent variable(s) and the composite error structure.

Econometrics

Proper specification of the disturbance structure and identification of the multiple independent variables are difficult problems in the estimation of rational distributed lag models. Burt (1978, 1980) introduced nonstochastic difference equations as a means of minimizing problems associated with separating the systematic component of the equation from its error structure. He justified using nonstochastic difference equations for three reasons. First, in stochastic difference equations the parameter estimates are biased and inconsistent if misspecification of the error structure occurs; however, by utilizing nonstochastic difference equations misspecification of the error structure does not result in inconsistent parameter estimates. Second, the complexity of the error structure through transformation of the initial rational lag specification is reduced when using the nonstochastic approach. And third, by using this approach the disturbance process is divorced from the systematic part of the equation, i.e., parameter estimates of an autoregressive error term are asymptotically uncorrelated with other parameter estimates in the model (Burt and Townsend 1980).

Specifying a model as nonstochastic changes the definition of the lagged dependent variable. Instead of specifying the lagged observed value of the dependent variable, the lagged "expected value" of the dependent variable is used. For example, a Koyck stochastic difference equation is

$$Y_t = a + bX_t + \lambda Y_{t-1} + e_t \qquad (7)$$

where e_t has the classical properties of zero mean, constant variance, and no serial correlation. Specifying a nonstochastic difference equation substitutes an unobservable lagged expected value of the dependent variable and is written as

$$Y_t = a + bX_t + \lambda E(Y_{t-1}) + e_t^* , \qquad (8)$$

where

$$e_t^* = \rho e_{t-1} + u_t , \qquad (9)$$

and u_t has the classical properties. Equation (8) is nonstochastic in that continuous iterations yields $E(Y_t)$ only as a function of the historical values of X. The expected value of the lagged dependent variable is a strictly exogenous variable even if the error term is autocorrelated. An estimation problem arises in using OLS when $E(Y_{t-1})$ and/or autocorrelated error structures are specified because of nonlinearities in the parameters. To circumvent this problem, a modified Marquardt nonlinear least squares algorithm is used in obtaining least squares estimates (maximum likelihood under the assumption of normality) for the nonstochastic difference equation (Burt and Townsend 1980).

Recursive Systems

Oftentimes, particularly in short-run periods, the pricing structure of agricultural commodities may follow a recursive pattern (Wold 1953). Such a system is hypothesized for the steer and heifer price model as it is assumed that in the cattle marketing chain seasonal prices determined at the carcass level are passed down to the slaughter level, and then slaughter prices enter at the feeder level. In such a system the dependent variables are determined in sequence. Thus the first dependent variable is determined in the first equation, independent of all other endogenous variables in the system; its value then recursively enters the next equation as a predetermined variable and the sequence continues to the next market level. As long as the error terms across the equations are uncorrelated, each equation is treated as a reduced form relation (Wonnacott and Wonnacott 1979).

Pricing Mechanisms

Price discovery is basically the process by which buyers and sellers arrive at a specific price or trade agreement. This can occur through negotiations between individuals or producer organizations, organized exchanges including auctions, and formula pricing. The cattle industry tends to engage in all of these types of pricing mechanisms.

Individual negotiated prices are oftentimes tied to the near futures market quotation, a price which approximates competitive market equilibrium price if accurate economic information is available to both buyers and sellers. There are adjustments to this price to account for differences in grade, quality and location. In organized exchanges and auctions prices are determined in a similar fashion (Tomek and Robinson 1981).

Formula pricing in tne beef industry occurs in the carcass and fabricated meat trade, and is based on Yellow Sheet price quotations.[1] The later is usually based on a small percentage of federally inspected steer and heifer slaughter. The formula price is arrived at through various adjustments to the Yellow Sheet price agreeable to buyer and seller. It is reported that 70 percent of steer and heifer carlot carcass sales are sold via formula pricing, with 24 percent of these sales made to packers who also engage in purchasing live cattle for slaughter. In addition, the Yellow Sheet (wholesale) beef price quotation is the principal guide used by packers in determining the live price bid on slaughter cattle entering the plant.[2]

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[1] The Yellow Sheet is published by the National Provisioner of Chicago.

[2] U.S., Department of Agriculture, "Beef Pricing Report," Agricultural Marketing Service, Packers and Stockyards Program (Washington, D.C.: December 1978).

CHAPTER 3

MODEL SPECIFICATION

The previous chapters were concerned with theoretical concepts and market characteristics necessary to model structural steer and heifer prices. What follows is a general model specification for each market level and the justification of the variables included in the maintained hypothesis.

Carcass Wholesale Market

The first price level considered is the beef carcass market. The behavior of steer and heifer carcass prices are assumed to be described by a rational distributed lag process. Consequently, the pricing behavior of packers and wholesalers is modeled by difference equations with specified lags on the independent variables (Jorgenson 1966). The rational generating function is applied to the exogenous variables of steer and heifer carcass production, substitute quantities, by-product values, income, and marketing margins. Implicitly the expectation process will not only be determined by the particular weight lag structure of the independent variables, but also by the order of the difference equation. In this model either first or second order difference equations are expected to typify the time frame in which wholesalers can make price adjustments.

The equations for the prices of steer and heifer carcasses and the premium relationship are:

$$PSC = f_1(D, QSHC_{t-j}, QPKPY_{t-j}, BPVC_{t-j}, Y_{t-j}, MCR_{t-j}, E(PSC)_{t-i}) \quad (10)$$

$$PHC = f_2(D, QSHC_{t-j}, QPKPY_{t-j}, BPVC_{t-j}, Y_{t-j}, MCR_{t-j}, E(PHC)_{t-i}) \quad (11)$$

$$PSC\text{-}PHC = f_3(D, QSHC_{t-j}, QPKPY_{t-j}, BPVC_{t-j}, Y_{t-j}, MCR_{t-j}, E(P')_{t-i}) \qquad (12)$$

$$j = 0, 1, \ldots, k \qquad i = 1,2, \ldots, p \qquad k \leqslant p$$

where

PSC = price of Choice, yield grade #3 steer carcasses, 600-700 lbs., Omaha, ($/cwt.), (endogenous).

PHC = price of Choice, yield grade #3 heifer carcasses, 600-700 lbs., Omaha, ($/cwt.), (endogenous).

QSHC = quantity of steer and heifer carcasses, (billions of lbs.), (exogenous).

OPKPY = quantity of commercial pork and young chicken supply, (billions of lbs.), (exogenous).

BPVC = by-product value for Choice, yield grade #3 beef carcasses, (cts./lb.), (exogenous).

Y = per capita disposable personal income, (current dollars), (exogenous).

MCR = beef carcass-to-retail margin, (cts./lb.), (endogenous).

D = seasonal dummy variables specific to three calendar quarters with the January through March period omitted.

E = expectation operator.

P′ = PSC-PHC = the arithmetic difference between steer and heifer carcass prices ($/cwt.), (endogenous).

All price variables are deflated by the Consumer Price Index (1972 = 100) and all quantity variables are deflated by population. Quarterly time series data from 1971 through 1982 are used to estimate the equations.[1] Binary variables account for seasonal shifts in the intercepts (first quarter omitted) since the data observations are pooled.

The model is specified to analyze the effects of economic variables on individual steer and heifer prices. These variables are then incorporated into a price premium equation to determine the statistical significance of their difference. The inclusion of the same variables in the price premium equation is logical since it is based on their hypothesized effects in

[1] It is implied that statistical error terms of lags t–j exist for this and all subsequent equations.

the individual equations. Direct estimation is employed over simply subtracting the individual equations. While subtraction would illustrate differences in parameter estimates, the procedure for testing their statistical significance would be complicated due to the subtraction of autocorrelated/moving average error structures.

A priori, the partial derivatives for Equations (10) and (11) are given as:

$$\frac{\partial \text{ PSC}}{\partial \text{ QSCH}} < 0 \qquad \frac{\partial \text{ PHC}}{\partial \text{ QSHC}} < 0 \tag{13}$$

$$\frac{\partial \text{ PSC}}{\partial \text{ QPKPY}} < 0 \qquad \frac{\partial \text{ PHC}}{\partial \text{ QPKPY}} < 0 \tag{14}$$

$$\frac{\partial \text{ PSC}}{\partial \text{ BPVC}} > 0 \qquad \frac{\partial \text{ PHC}}{\partial \text{ BPVC}} > 0 \tag{15}$$

$$\frac{\partial \text{ PSC}}{\partial \text{ Y}} > 0 \qquad \frac{\partial \text{ PHC}}{\partial \text{ Y}} > 0 \tag{16}$$

$$\frac{\partial \text{ PSC}}{\partial \text{ MCR}} < 0 \qquad \frac{\partial \text{ PHC}}{\partial \text{ MCR}} < 0. \tag{17}$$

Sign expectations (13) through (17) follow from the specification of the reduced form Equations (10) and (11). If the quantity of a commodity increases, its price decreases; if quantity of substitutes increase, the prices of the substitutes decrease and reduces own price through the demand response process. If the value of carcass by-products increase (decrease) the price of beef carcasses is expected to increase (decrease) since the overall value of carcasses increase (decrease). This is particularly important in the beef processing industry since, for individual firms, returns from by-products frequently cover their processing costs. It is expected that as consumer incomes increase primary demand increases, hence, beef consumption increases. This process feeds directly into the wholesale sector, raising the prices of carcass and fabricated products. Changes in the marketing margin due to cost changes shift market derived demand and supply curves (Tomek and Robinson 1981). For example, an increase in the carcass-retail marketing margin would, ceteris pari-