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

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Robert William Schultz

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

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

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

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

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

$$Q_t = bW(L)P_t + e_t \tag{3}$$

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

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

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-

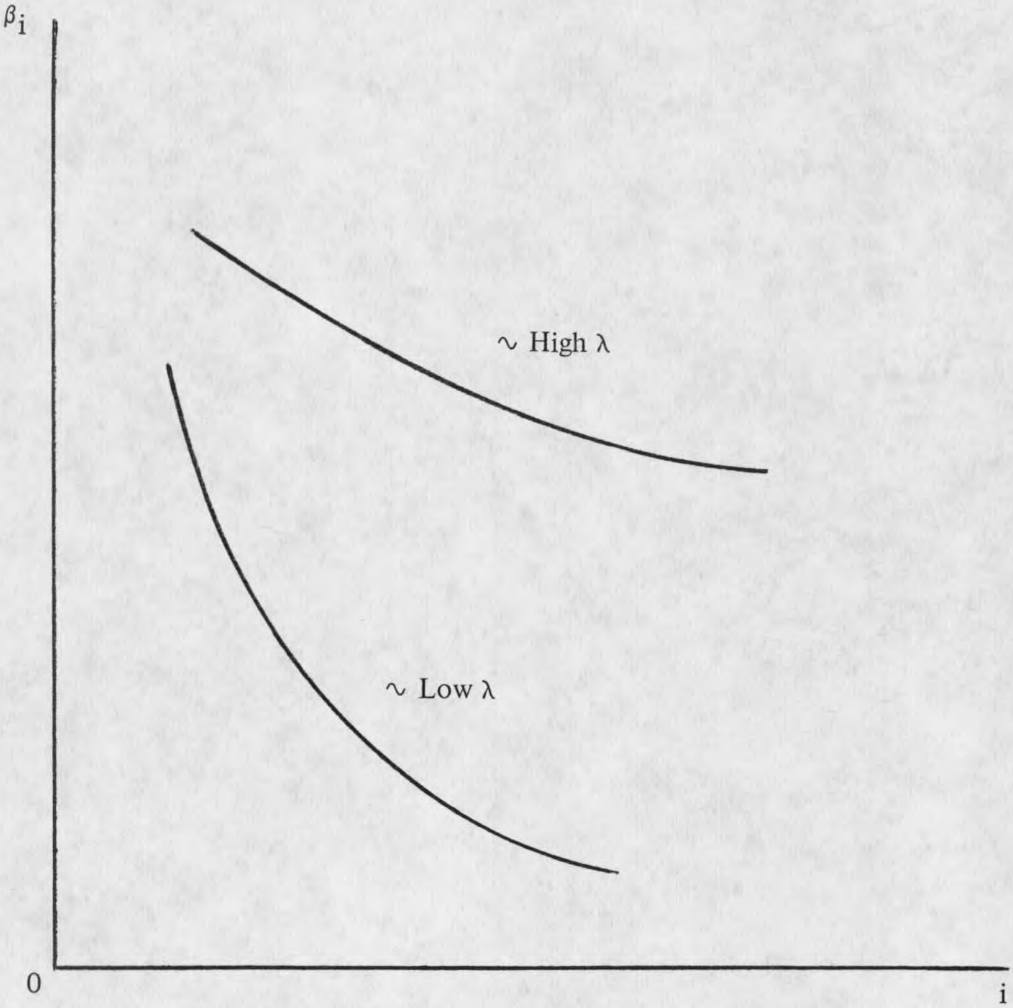

Figure 1. Koyck geometric lag.

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

$$Q_t = bW(L)P_t + e_t \tag{5}$$

where

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

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 $m \leqslant n$. 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

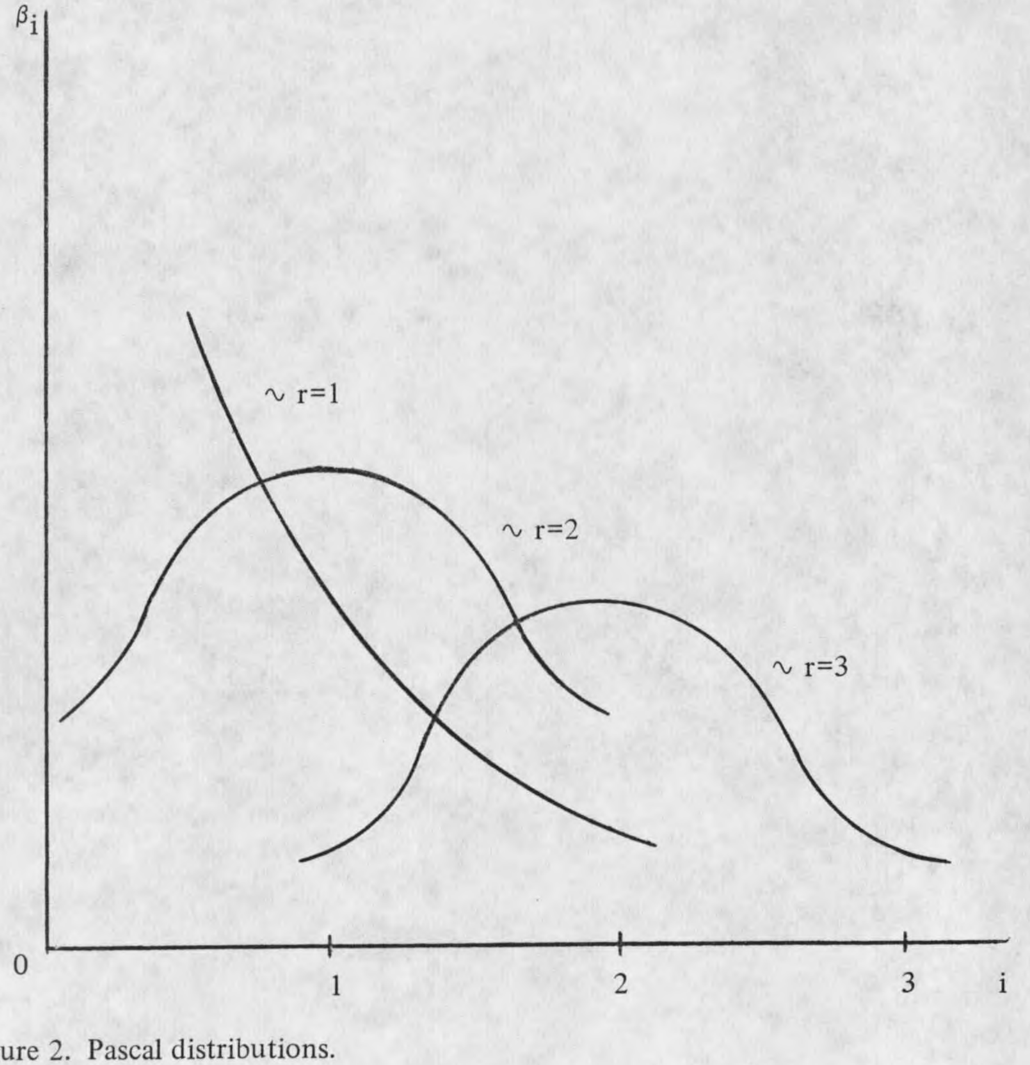

Figure 2. Pascal distributions.

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

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

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:

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

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

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

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

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:

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

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

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

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

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

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 paribus, cause a retail buyer to bid down the price of carcasses since primary demand is not perfectly inelastic.

Slaughter Market

The second price level considered is the slaughter market. At this level the maintained hypothesis regarding lag structures is different than those in the carcass market. That is, past values of the independent variables have a weaker influence on the dependent variables. The rationale for this lies in the nature of the industry itself. The USDA has shown that packer bids on live cattle quickly adjust to changes in wholesale prices. Also the holding and storing capacities of live cattle inputs by slaughterers is quite limited. Consequently, adjustments in slaughter cattle price as a result of economic changes in the feeder and carcass markets are quite rapid. The following equations represent the individual steer and heifer slaughter prices and their price difference

$$PSS = f_4(D, QFS_{t-j}, QNFS_{t-j}, PSC_{t-j}, BPVF_{t-j}, E(PSS)_{t-i}) \quad (18)$$

$$PSH = f_5(D, QFS_{t-j}, QNFS_{t-j}, PSC_{t-j}, BPVF_{t-j}, E(PSH)_{t-i}) \quad (19)$$

$$PSS\text{-}PSH = f_6(D, QFS_{t-j}, QNFS_{t-j}, PSC_{t-j}, BPVF_{t-j}, E(P')_{t-i}) \quad (20)$$

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

where

PSS = price of Choice, yield grade #3 slaughter steers, 900-1100 lbs., Iowa ($/cwt.), (endogenous).

PSH = price of Choice, yield grade #3 slaughter heifers, 900-1100 lbs., Iowa, ($/cwt.), (endogenous).

QFS = quantity of commercial cattle slaughter of fed steers and heifers (millions of head), (exogenous).

QNFS = quantity of commercial cattle slaughter of nonfed steers and heifers (millions of head), (exogenous).

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

BPVF = by-product value for Choice yield grade #3 slaughter steers (cts./lb.), (exogenous).

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

P′ = PSS-PSH = arithmetic difference between slaughter steer and heifer prices, (\$/cwt.), (endogenous).

Deflation procedures correspond to those of the carcass level. A priori the signs of the partial derivatives for Equations (18) and (19) are

$$\frac{\partial PSS}{\partial QFS} < 0 \qquad \frac{\partial PSH}{\partial QFS} < 0 \tag{21}$$

$$\frac{\partial PSS}{\partial QNFS} < 0 \qquad \frac{\partial PSH}{\partial QNFS} < 0 \tag{22}$$

$$\frac{\partial PSS}{\partial PSC} > 0 \qquad \frac{\partial PSA}{\partial PSC} > 0 \tag{23}$$

$$\frac{\partial PSS}{\partial BPVF} > 0 \qquad \frac{\partial PSH}{\partial BPVF} > 0 \tag{24}$$

Slaughtering firms usually process different livestock species of which fed and nonfed cattle are major types (however, since World War II there has been a trend toward horizontal specialization). These animals constitute the slaughtering firm's inputs, while the carcasses (halves and quarters), fabricated carcasses, and by-products constitute their output. The carcass market has been declining relative to fabricated and boxed beef, nevertheless the principle of price determination is the same. Economic theory suggests that increases in the number of fed and nonfed slaughter cattle would have a negative impact on the price of slaughter steers and heifers. Also, the prices slaughtering firms are willing to bid on slaughter cattle are determined by prices they receive for the output, carcasses. If carcass prices increase, then slaughter cattle prices increase as packers demand more slaughter cattle. By-products constitute an important output for packers since they oftentimes cover packer costs and profit margins. An expected result of increased by-product values would be an increase in the price of slaughter cattle.

Feeder Market

Cattle feeders purchase live animal inputs from cow-calf and cow-yearling producers. Therefore, the analysis at this market level is divided into: (1) prices of 400-500 pound feeder steer and heifer calves, and (2) prices of 600-700 pound yearling steers and heifers. The following equations represent the prices in the feeder cattle sector:

$$PFS4\text{-}5 = f_7(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(PFS4\text{-}5)_{t-i}) \quad (25)$$

$$PFH4\text{-}5 = f_8(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(PFH4\text{-}5)_{t-i}) \quad (26)$$

$$PFS6\text{-}7 = f_9(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(PFH6\text{-}7)_{t-i}) \quad (27)$$

$$PFH6\text{-}7 = f_{10}(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(PFH6\text{-}7)_{t-i}) \quad (28)$$

$$PFS\text{-}PFH4\text{-}5 = f_{11}(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(P')_{t-i}) \quad (29)$$

$$PFS\text{-}PFH6\text{-}7 = f_{12}(D, PSS_{t-j}, QFS_{t-j}, QFH_{t-j}, MFC_{t-j}, PC_{t-j}, E(P'')_{t-i}) \quad (30)$$

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

where

PFS4-5 = price of medium frame #1 feeder steer calves, 400-500 lbs., Kansas City, ($/cwt.), (endogenous).

PFH4-5 = price of medium frame #1 feeder heifer calves, 400-500 lbs., Kansas City, ($/cwt.), (endogenous).

PFS6-7 = price of medium frame #1 feeder steers, 600-700 lbs., Kansas City, ($/cwt.), (endofenous).

PFH6-7 = price of medium frame #1 feeder heifers, 600-700 lbs., Kansas City, ($/cwt.), (endogenous).

PSS = price of Choice, yield grade #3 slaughter steers, 900-1100 lbs., Iowa, ($/cwt.), (endogenous).

QFS = quantity of steers on feed, 13 states, millions of head, (endogenous).

QFH = quantity of heifers on feed, 13 states, millions of head, (endogenous).

MFC = farm-to-carcass marketing margin, cents/lb., (endogenous).

PC = price of #2 yellow corn, Omaha, ($/bu.), (exogenous).

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

P′ = PFS4-5 – PFH4-5 = arithmetic difference between feeder steer and heifer calf prices, ($/cwt.), (endogenous).

P″ = PFS6-7 – PFH6-7 = arithmetic difference between feeder steer and heifer hearling prices, ($/cwt.), (endogenous).

Deflation procedures are the same as at the previous market levels. The expected signs given by the partial derivatives in Equations (25) through (28) are

$$\frac{\partial\, PFS4\text{-}5}{\partial\, PSS} > 0 \qquad \frac{\partial\, PFH4\text{-}5}{\partial\, PSS} > 0 \tag{31}$$

$$\frac{\partial\, PFS6\text{-}7}{\partial\, PSS} > 0 \qquad \frac{\partial\, PFH6\text{-}7}{\partial\, PSS} > 0$$

$$\frac{\partial\, PFS4\text{-}5}{\partial\, QFS} < 0 \qquad \frac{\partial\, PFH4\text{-}5}{\partial\, QFS} < 0 \tag{32}$$

$$\frac{\partial\, PFS6\text{-}7}{\partial\, QFS} < 0 \qquad \frac{\partial\, PFH6\text{-}7}{\partial\, QFS} < 0$$

$$\frac{\partial\, PFS4\text{-}5}{\partial\, QFH} < 0 \qquad \frac{\partial\, PFH4\text{-}5}{\partial\, QFH} < 0 \tag{33}$$

$$\frac{\partial\, PFS6\text{-}7}{\partial\, QFH} < 0 \qquad \frac{\partial\, PFH6\text{-}7}{\partial\, QFH} < 0$$

$$\frac{\partial\, PFS4\text{-}5}{\partial\, MFC} < 0 \qquad \frac{\partial\, PFH4\text{-}5}{\partial\, MFC} < 0 \tag{34}$$

$$\frac{\partial\, PFS6\text{-}7}{\partial\, MFC} < 0 \qquad \frac{\partial\, PFH6\text{-}7}{\partial\, MFC} < 0$$

$$\frac{\partial\, PFS4\text{-}5}{\partial\, PC} < 0 \qquad \frac{\partial\, PFH4\text{-}5}{\partial\, PC} < 0 \tag{35}$$

$$\frac{\partial\, PFS6\text{-}7}{\partial\, PC} < 0 \qquad \frac{\partial\, PFH6\text{-}7}{\partial\, PC} < 0$$

The inclusion of slaughter steer price in the calf and yearling price equations measures cattle feeders' response to changes in output price. It is expected that an increase (decrease) in slaughter steer price will increase (decrease) feeder steer and heifer prices due to changes in the demand for feeder cattle.

The numbers of steers and heifers on feed, QFS and QFH, are treated as supply variables. If there is either an increase or decrease in numbers on feed it is expected, ceteris paribus, that feeder prices will move in the respective opposite direction.

The farm-to-carcass marketing margin includes costs incurred in transporting steers and heifers from feedlots to packers, and then processing them into carcasses. The major costs in addition to transportation include transaction costs, variable costs associated with capital machinery (including energy), and wages. It is expected that a negative correlation exists between margins and feeder prices since higher marketing costs cause feeders to adjust their profit margins by offering lower feeder cattle prices.

Corn price is used as a proxy for feed costs of gain. Though other feedgrains are utilized in cattle rations, changes in the corn market tend to lead prices of other feedgrains. A negative correlation between corn price and price of both feeder steers and heifers is expected since higher feed costs increase the per unit cost of producing finished cattle. The result is a decrease in the derived demands for steers and heifers of both weight categories.

It should be concluded that for all three market levels (carcass, slaughter, and feeder), though a priori impacts of the independent variables on individual steer and heifer prices were discussed, the relative impacts on steer versus heifer prices are expected to differ. Biological as well as economic conditions are hypothesized to account for these differences. With respect to the feeder level, this also includes differences between weight categories. However, the discussions of these comparisons are left for the next chapter.

CHAPTER 4

EMPIRICAL RESULTS

The preceding chapter discussed the model specification for the carcass, slaughter, and feeder steer and heifer prices. The model consisted of eight individual reduced form price equations and four price premium equations. Tables 1 through 8 present the statistical results of the structural equations and their price flexibilities based on their distributed lag patterns. It should be noted that the following empirical results present the final estimates. They are considered best since other specifications with different lags on the dependent and independent variables and the error terms were tried. The adjusted R^2, standard error of equation, and individual t ratios were jointly considered in making the decisions.

Carcass Wholesale Market

The steer and heifer carcass price equations are estimated as first order nonstochastic difference equations with no serial correlation. Table 1 presents the statistical results of the regression coefficients and the equation fits. All asymptotic t values (except those of the intercepts) indicate that coefficient estimates are significantly different from zero at a 95 percent probability level. For all independent variables the order and magnitude of the estimated coefficient on the lagged dependent variable suggest a declining geometric weight structure with a slow rate of adjustment ($\lambda = .96$).

The estimated coefficient on the quantity of substitutes variable, QPKPY, had a positive sign in the regression results. Individual specification of pork and poultry was equally unsuccessful. Since this conflicts with theoretical reasoning, the price flexibilities for various time periods were not calculated. Freebairn and Rausser (1975) had similar problems

Table 1. Statistical Results of Quarterly Steer and Heifer Carcass Prices and Price Difference.

	Variables[a]												
Equation	Constant	D2	D3	D4	QSHC	QSHC-1	QPKPY	BPVC	BPVC-1	Y	Y-1	MCR	E(DEP-1)[b]
PSC	-11.478 (-1.630)	-.559 (-.681)	-1.606 (-2.378)	-2.004 (-2.394)	-13.638 (-5.124)	10.943 (3.215)	1.978 (7.676)	11.572 (4.210)	-7.417 (-2.657)	.023 (4.805)	-.016 (-3.608)	-.442 (-4.838)	.959 (14.441)
PHC	-7.893 (-1.095)	-.995 (-1.189)	-2.257 (-3.420)	-2.051 (-2.522)	-14.150 (-5.452)	10.979 (3.267)	1.813 (6.967)	13.055 (4.920)	-8.613 (-3.128)	.021 (4.407)	-.015 (-3.402)	-.382 (-4.231)	.942 (13.704)
PSC-PHC	-1.157 (-.984)	.150 (.657)	.477 (2.095)	.278 (1.220)	.899 (1.653)	———	———	———	———	———	———	———	———

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.030 for a 95 percent probability level (degrees of freedom are 35).

[b] Represents the expected value of the lagged dependent variable.

[c] Regression results for PSC are: adjusted multiple R-squared statistic ($\bar{R}^2$) = .955, standard error of estimate (SY) = 1.185, and Durbin-Watson statistic (DW) = 2.039. For PHC: $\bar{R}^2$ = .955, SY = 1.164, and DW = 1.944. For PSC-PHC: $\bar{R}^2$ = .074, SY = .546, and DW = 1.703.

with substitutes in retail demand equations, however, Brester (1982) showed substitutes to be significant with the correct sign for retail beef prices.

The sum of the regression coefficients specific to the quantity of steer and heifer carcass variables are negative, satisfying theoretical expectations. In Table 2 the price flexibilities illustrate the slow rate of adjustment. Through the first 8 quarters it appears that heifer price may be slightly more sensitive to quantity changes than steer price. Estimates for the long-run indicate the opposite. However, this observation is only based on arithmetic differences in the price flexibilities and is not based on any statistical test. In both cases the long-run price flexibilities are considerably higher than the short-run flexibilities since, overtime, processing firms adjust to changes in supply conditions in the market. Some of the short-run constraints include fixed processing and storage capacity and lack of complete information on demand and production conditions.

The value of carcass by-products is highly significant in affecting short- and long-run adjustments in steer and heifer carcass prices. The positive correlation was expected since increases in the value of by-products increase the per unit values of steer and heifer carcasses. The heifer carcass price appears to be more sensitive in the short-run while the steer price appears more sensitive in the long-run (based on arithmetic differences of the price flexibility coefficients). For a period of one quarter, a 10 percent increase in by-product value, leads to an increase in steer and heifer prices by 3.0 and 3.5 percent, respectively. Over the long-run the same 10 percent increase produces a 26.2 and 20.7 percent increase in the respective carcass prices.

Disposable income is a shifter of primary demand, reflecting consumer purchasing power. These changes in purchasing power are reflected to the steer and heifer carcass market. The results reveal a positive income effect. For example, for a period of one quarter, a $100 increase in income will lead to an increase in steer carcass price by 2.3 cents per pound and heifer carcass price by 2.1 cents per pound. The estimated distributed lag pat-

Table 2. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Steer and Heifer Carcass Market.

	Quarters				
Equation	1	2	4	8	Long-run
PSC/QSHC	-13.638 (-.700)	-15.769 (-.809)	-19.769 (-1.014)	-26.822 (-1.376)	-65.105 (-3.340)
PHC/QSHC	-14.150 (-.744)	-16.506 (-.868)	-20.820 (-1.094)	-28.054 (-1.475)	-55.081 (-2.895)
PSC/BPVC	11.572 (.302)	15.249 (.399)	22.151 (.579)	34.324 (.897)	100.39 (2.624)
PHC/BPVC	13.055 (.350)	16.746 (.448)	23.502 (.629)	34.832 (.933)	77.163 (2.066)
PSC/Y	.023 (1.770)	.030 (2.308)	.042 (3.231)	.063 (4.847)	.178 (13.695)
PHC/Y	.021 (1.655)	.026 (2.049)	.035 (2.759)	.051 (4.020)	.109 (8.592)
PSC/MCR	-.442 (-.330)	-.866 (-.647)	-1.661 (-1.241)	-3.064 (-2.289)	-10.676 (-7.975)
PHC/MCR	-.382 (-.292)	-.741 (-.567)	-1.400 (-1.071)	-2.504 (-1.916)	-6.629 (-5.073)
PSC-PHC/QSHC[b]	.899 (1.928)	———	———	———	———

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

[b] Carcass price difference equations were estimated as static models, therefore, partial derivatives and price flexibilities were calculated for the first quarter only.

terns indicate that the income effect is highly significant on the dressed meat trade since the price flexibility coefficients for all time periods exceed 1.0.

The sign on the coefficient estimates for the carcass-to-retail marketing margin variable meet a priori expectations. Increased margins caused by increased per unit processing and distribution costs lead to decreased demand for steer and heifer carcasses. The price flexibility coefficients are less than 1.0 for a time period less than one year, but are "flexible" (> 1.0) for a period of one year or more. This suggests that for short periods of time there may be relatively quick supply adjustments through changes in cold storage holdings, thus, more of the cost increase may be passed on to consumers. Over the longer term, plant adjustments can be made and processors may absorb more of the margin increase. Since the margin is jointly dependent with retail and carcass prices, predicted values of the margin from a reduced form equation were entered in the carcass price equation. Theoretically, this should purge correlation between the margin variable and the error structure.

It should be remembered that although arithmetic differences exist between steer and heifer price flexibilities, their significance is not readily determined. Thus, the differences are estimated directly. Regression results reported in Table 1 reveal the only significant exogenous variable (at the 90 percent probability level) to influence steer premiums in the wholesale market is the production of steer and heifer carcasses.[1] However, its adjusted R^2 is extremely low, indicating that the proportion of the variation accounted for by the explanatory variables is small. The data shows the mean steer-heifer difference to be only $.998 per cwt. with a standard deviation of $.561 per cwt. revealing little actual variation to be explained.

Given these results above, the price flexibilities (with respect to carcass production) indicate that the heifer carcass price tends to be discounted more during periods of

[1] Quantities of steer and heifer carcasses were tested as separate production variables. However, due to high collinearity between the regressors, the asymptotic t values were not significantly different from zero.

increased production. That is, higher quality steer carcasses may be exploited to a firm's advantage during periods of higher production. From Table 2, a 10 percent increase in carcass production yields a 19.3 percent increase in the steer-heifer carcass price difference. The entire adjustment takes place in the contemporaneous quarter. Thus, we can conclude that quality accounts for some of the steer-heifer carcass price difference, with deviations from quality only partly accounted for by production and the remainder attributed to random fluctuations. Such random occurrences may be due to a lack of information in the market, uncertainty, and perhaps inaccuracies in formula pricing.

Slaughter Market

The final slaughter steer and heifer price equations are estimated as static functions. This may not be too surprising since buying cattle inputs and selling carcasses and fabricated products are performed by the same firm. Since cattle buying is dominated by wholesale prices, rather quick adjustments in slaughter prices would be expected. The independent variables include the contemporaneous values of the price of steer carcasses, by-product values, and the quantities of fed and nonfed slaughter. The price of steer carcasses was estimated as an instrument variable, and its predicted value entered in the equation to purge possible correlation with the error term. Table 3 gives the statistical results for each price equation. Satisfactory adjusted R^2's and standard errors of equations were obtained. Since adjustments in prices are not influenced by either past values of the independent or dependent variables, the partial derivatives and price flexibilities in Table 4 are calculated for only the contemporaneous quarter.

The value of the output of packers and processors, beef carcasses and by-products, play a major role in the pricing of slaughter steers and heifers. This is confirmed by coefficient estimates that have highly significant asymptotic t ratios. The positive signs of the coefficient estimates also meet a priori expectations. A 10 percent increase in the price of

Table 3. Statistical Results of Quarterly Slaughter Steer and Heifer Prices and Price Difference.

	Variables[a]								Statistics[b]		
Equation	Constant	D2	D3	D4	PSC	BPVF	QFS	QNFS	$\bar{R}^2$	SY	DW
PSS	3.331 (1.649)	.203 (.603)	.276 (.807)	-.045 (-.131)	.540 (19.149)	.483 (5.008)	-.689 (-1.359)	-1.719 (-2.503)	.957	.798	1.839
PSH	5.080 (2.500)	.090 (.265)	.184 (.536)	-.040 (-.115)	.493 (17.406)	.487 (5.014)	-.849 (-1.644)	-2.127 (-3.079)	.951	.802	2.222
PSS-PSH	-.840 (-1.424)	.139 (1.088)	.107 (.747)	-.010 (-.075)	.038 (2.718)	———	———	———	.331	.372	1.989

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.030 for a 95 percent probability level (degrees of freedom are 40).

[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
SY = standard error of the estimate.
DW = Durbin-Watson statistic.

steer carcasses results in an 8.5 percent increase in the slaughter steer price and an 8.0 percent increase in the slaughter heifer price. This result reflects the fact that an increase in the market value of carcasses increases the derived demand for slaughter inputs. These results appear consistent with short-run effects of carcass price changes on slaughter prices as calculated by Brester and Marsh (1983).

By-products in the slaughter sector have the same importance as in the carcass sector, i.e., they serve to cover processing costs and profit margins. Consequently, when their values increase, the overall value of the live animal increases. This hypothesis is supported by the positive sign of the coefficient estimates. The price flexibility coefficients show that a 10 percent increase in by-products increases steer and heifer slaughter prices by 1.3 percent.

The negative coefficient signs specific to the quantities of fed and nonfed slaughter are consistent with economic theory. The results reveal that fed slaughter has a greater direct impact on fed steer and heifer prices than nonfed slaughter (i.e., about three times when comparing the flexibility coefficients). This is expected since nonfed slaughter (cull stock and range fed cattle) is a competitive product to the cattle finishing industry. These results are also consistent with other similar work (Brester and Marsh, 1983; Marsh 1983a).

The initial specification of the slaughter steer-heifer price difference equation, (PSS – PSH), included the set of exogenous variables in the individual equations. However, coefficient estimates of all variables except the price of steer carcasses were found to be insignificant (Table 4). The price variable, PSC, was positively correlated with the steer-heifer price difference since an increase in the price of carcasses leads packers to bid relatively higher on the slaughter steer inputs. The output prices of steer and heifer carcasses were tested separately, however, high multicollinearity between the two precluded their individual statistical significance (although the signs were correct). In the absence of collinearity, the

Table 4. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Slaughter Steer and Heifer Market.

	Variables[a]			
Equation	PSC	BPVF	QFS	QNFS
PSS	.540 (.847)	.483 (.126)	-.698 (-.076)	-1.719 (-.026)
PSH	.493 (.797)	.487 (.131)	-.849 (-.095)	-2.127 (-.033)
PSS-PSH	.038 (1.969)	———	———	———

[a] The top figures represent partial derivatives and the figures in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure is representative of a first quarter effect of an independent variable on a dependent variable.

economic significance suggests that differences in steer and heifer carcass prices impact the difference in slaughter steer and heifer prices. Statistically, a 10 percent increase in price of steer carcasses increases the price difference by 19.7 percent.

The mean steer-heifer price difference for the slaughter sector is also very small (as was found in the carcass sector) with a mean of \$.80 per cwt. and a standard deviation of \$.45 per cwt. Given quality differences and a small adjusted R^2 (.33), it appears that random factors and not economic variables explain the majority of the steer-heifer slaughter price premium relationship. The absence of lagged variables also suggests that the premium relationship is not dynamic, remaining current with any random and systematic changes in the market.

Feeder Market

The statistical results for the 400-500 and 600-700 pound feeder steer and heifer price equations are presented in Table 5. All models were estimated as first order nonstochastic difference equations with first order positive serial correlation. The adjusted R^2's and standard errors of equations (SY's) indicated a satisfactory model specification. The coefficients on the lagged dependent variables are relatively small indicating that the rate of geometric decline for all the dependent price variables is fairly rapid.

Slaughter steer price is crucial in determining the prices of both weight categories of feeder steers and heifers. To take account of possible joint dependency, slaughter prices were estimated as instrument variables. At first hand, there appears to be some noticeable arithmetic differences of the effects of slaughter prices on steer price versus heifer price both within and across weight categories. That is, the regression coefficients show steer price to be more highly impacted than heifer price when there is a change in slaughter price, and both steers and heifers to be more highly impacted in the 400-500 lb. weight range than in the 600-700 lb. weight range. However, the short- and long-run price flexibilities

Table 5. The Statistical Results of Quarterly Steer and Heifer Feeder Prices and Price Difference.

Equation	Variables[a]										Statistics[b]		
	Constant	D2	D3	D4	PSS	QFS	QFH	PC	MFC	E(DEP-1)	$\bar{R}^2$	SY	DW
PFS4-5	-18.859	-.675	-.494	1.138	1.039	2.684	7.629	-1.911	-1.958	.491	.971	1.508	1.957
	(-4.009)	(-.996)	(-.546)	(1.367)	(9.074)	(1.343)	(2.171)	(-1.724)	(-3.946)	(6.940)			
PFH4-5	-18.058	-.258	.369	1.245	.859	3.145	6.772	-1.833	-1.765	.487	.976	1.192	1.979
	(-4.890)	(-.481)	(.513)	(1.841)	(9.419)	(1.974)	(2.449)	(-2.111)	(-4.489)	(7.535)			
PFS4-5-PFH4-5	-2.866	-.268	-.721	.087	.176	-.745	2.364	———	———	.459	.750	.570	2.022
	(-2.801)	(-1.060)	(-2.694)	(.328)	(4.292)	(-2.518)	(3.375)			(3.400)			
PFS6-7	-13.984	-.568	.116	1.706	.939	2.735	4.895	-1.064	-1.624	.383	.965	1.239	1.990
	(-3.491)	(-1.034)	(.156)	(2.471)	(9.686)	(1.623)	(1.659)	(-1.126)	(-4.003)				
PFH6-7	-12.118	-.295	.570	1.540	.809	3.215	3.908	-1.310	-1.685	.385	.972	1.002	1.990
	(-3.737)	(-.659)	(.926)	(2.659)	(10.293)	(2.304)	(1.627)	(-1.705)	(-5.123)	(5.248)			
PFS6-7-PFH6-7	-1.743	-.293	-.464	.175	.136	-.447	1.017	.211	———	.348	.808	.345	1.787
	(-2.068)	(-2.038)	(-2.712)	(1.107)	(5.328)	(-1.411)	(1.552)	(.900)		(2.230)			

[a] The asymptotic t ratios are given in parentheses below each coefficient. The critical boundary is 2.030 for a 95 percent probability level (degrees of freedom are 36).

[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
SY = standard error of the equation.
DW = Durbin-Watson statistic.

shown in Tables 6 and 7 show the tendencies in their differences to dissipate. In all cases, feeder steer and heifer price adjustments stabilize at about 6 quarters (not shown).

The price of corn serves as a proxy for cost of gain in the feedlot. Work by Buccola and Jessee (1979) and Marsh (1983) have shown corn prices to be highly significant in determining derived demand, hence, prices bid on feeder cattle. Results of this study show the correct signs (negative) but not particularly strong t values, particularly with respect to the price of 600-700 pound feeder steers. For light and heavy steers and heifers the adjustment of feeder prices stabilizes between 1 to 2 years from a given change in corn price. The price flexibilities reveal that for a period of 4 quarters, a 10 percent increase in corn price decreases light cattle price of both sexes roughly 1.7 percent, heavier steers .8 percent, and heavier heifers 1.2 percent. In discussing this phenomenon with cattle feeders, it was suggested that when feed costs increase they are more concerned about the number of days on feed versus feed conversion efficiency between steers and heifers. Therefore, it appears that increased feed costs first leads to a shift in feeding relatively more heavier cattle compared to lighter cattle, and then concern is placed on feeding relatively more steers versus heifers. The model results seem to confirm this reasoning.

The effect of the marketing margin denotes a negative correlation in the price equations. This is consistent with theoretical precepts since increased marketing costs reduce the derived demand for steers and heifers. For a period of one quarter, a 10 percent increase in the margin shows an approximate 3 percent decrease in prices for light and heavy cattle of both sexes. It appears that feeder prices adjust to a change in the margin by the eighth quarter. Also it can be seen that the long-run price flexibilities become less inflexible, yet less than 1.0. Margins have the potential to be correlated with the error structure because of their relationship with feeder prices. Consequently, the predicted value of the margin from a reduced form equation (instrument variable) was substituted for the observed value in the right hand side of the equation.

Table 6. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Feeder Steer and Heifer Market, 400-500 lbs.

	Quarters				
Equation	1	2	4	8	Long-run
PFS4-5/PSS	1.039 (.885)	1.548 (1.318)	1.922 (1.637)	2.034 (1.732)	2.040 (1.737)
PFH4-5/PSS	.859 (.869)	1.277 (1.292)	1.580 (1.599)	1.669 (1.689)	1.675 (1.695)
PFS4-5/PC	-1.911 (-.085)	-2.849 (-.127)	-3.536 (-.157)	-3.742 (-.166)	-3.754 (-.167)
PFH4-5/PC	-1.833 (-.097)	-2.726 (-.144)	-3.373 (-.178)	-3.563 (-.188)	-3.575 (-.189)
PFS4-5/MFC	-1.958 (-.295)	-2.919 (-.440)	-3.623 (-.546)	-3.833 (-.577)	-3.846 (-.579)
PFH4-5/MFC	-1.765 (-.316)	-2.625 (-.470)	-3.248 (-.581)	-3.431 (-.614)	-3.441 (-.616)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

Table 7. Partial Derivatives and Price Flexibilities of the Distributed Lags in the Feeder Steer and Heifer Market, 600-700 lbs.

	Quarters				
Equation	1	2	4	8	Long-run
PFS6-7/PSS	.939 (.882)	1.299 (1.221)	1.490 (1.400)	1.522 (1.430)	1.523 (1.431)
PFH6-7/PSS	.809 (.860)	1.120 (1.190)	1.285 (1.366)	1.313 (1.396)	1.314 (1.397)
PFS6-7/PC	-1.064 (-.052)	-1.472 (-.072)	-1.688 (-.083)	-1.725 (-.084)	-1.726 (-.085)
PFH6-7/PC	-1.310 (-.073)	-1.813 (-.101)	-2.082 (-.116)	-2.127 (-.118)	-2.128 (-.118)
PFS6-7/MFC	-1.624 (-.270)	-2.247 (-.374)	-2.577 (-.428)	-2.633 (-.438)	-2.634 (-.439)
PFH6-7/MFC	-1.685 (-.317)	-2.333 (-.439)	-2.678 (-.504)	-2.736 (-.514)	-2.738 (-.515)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

The statistical results for the cattle on feed variables, QFS and QFH, indicate a positive correlation exists with the endogenous price variables (for each sex and weight category). It is suspected that joint dependency between these variables would cause the results to conflict with theoretical expectations of negative price and quantity relationships. An effort to eliminate joint dependency included estimating QFS and QFH as instrument variables, however, it was unsuccessful. Consequently, calculation of the distributed lags for these quantity variables was omitted.

The means and variances of the differences between feeder steer and heifer prices (specific to the PFS4-5 - PFH4-5 and PFS6-7 - PFH6-7 equations) are signficantly greater than found at the other market levels. This increases the likelihood that economic variables contribute to the explained sum of squares, which is particularly evident with greatly improved regression fits (Table 5). The statistical results also show that the price differences are characterized by rapid declining geometric weight structures as evidenced in the individual price equations. All parameter signs meet a priori expectations.

The effects of a change in the price of slaughter steers are similar to that found in the individual price equations. That is, higher slaughter steer price tends to increase the feeder price spread since there is a proportionately greater increase in demand for feeder steers compared to feeder heifers. This is due both to quality factors and feed conversion as discussed earlier. With a 10 percent increase in slaughter steer price, over a period of 4 quarters the price differences for both weight categories increase about 17 percent (Table 8). Four quarters also tends to approximate the majority of the adjustment period.

The supply variables demonstrate the inverse relationship between prices and quantities. Logically one would expect that an increase in the number of steers on feed would decrease the steer-heifer price spread, while an increase in the number of heifers on feed would increase it. The price flexibilities in Table 8 support this hypothesis. Also, the price flexibilities show that lighter cattle prices are more sensitive to these quantity on feed

Table 8. Partial Derivatives and Price Flexibilities of the Distributed Lags for the Price Differences in Feeder Steers and Heifers, 400-500 lbs. and 600-700 lbs.

	Quarters				
Equation	1	2	4	8	Long-run
PFS-PFH4-5/PSS	.176 (.946)	.256 (1.376)	.310 (1.666)	.324 (1.741)	.325 (1.747)
PFS-PFH4-5/QFS	-.745 (-.452)	-1.087 (-.660)	-1.316 (-.799)	-1.374 (-.834)	-1.377 (-.836)
PFS-PFH4-5/QFH	2.364 (.674)	3.448 (.983)	4.175 (1.190)	4.360 (1.243)	4.368 (1.245)
PFS-PFH6-7/PSS	.136 (1.103)	.184 (1.492)	.206 (1.671)	.209 (1.695)	.209 (1.695)
PFS-PFH6-7/QFS	-.447 (-.409)	-.603 (-.552)	-.676 (-.619)	-.686 (-.628)	-.686 (-.628)
PFS-PFH6-7/QFH	1.017 (.437)	1.371 (.590)	1.538 (.662)	1.560 (.671)	1.561 (.671)
PFS-PFH6-7/PC	.211 (.089)	.284 (.120)	.319 (.135)	.323 (.137)	.324 (.137)

[a] The top figures represent the partial derivatives and the figures below in parentheses are the price flexibility coefficients (calculated at the mean values of the variables). Each figure represents the cumulative effects over the indicated quarterly periods.

changes than heavier cattle prices. Between light cattle sexes, the heifers, compared to steers, are about 60 percent more responsive in the long-run, but between heavier cattle sexes the responses are similar.

Interestingly enough, the cost of gain variable is not significant in the light cattle price difference equation and is only marginally significant in the heavier cattle price difference equation. Work by Marsh (1983b) shows that the cost of gain variable is most significant when analyzing its impact across weight categories for the same sex (i.e., 300-500 lb. steer calves versus 600-700 lb. steer yearlings). Price flexibility estimates here show that a 10 percent increase in corn price increases the price spread for 600-700 lb. steers and heifers by 1.4 percent over a period of 4 quarters. This likely illustrates that cattle feeders are less sensitive about feed conversion between steers and heifers for light cattle, but give it more weight when considering finishing heavier cattle.

CHAPTER 5

SUMMARY AND CONCLUSIONS

The purpose of this study was to identify and evaluate economic factors that influence steer and heifer prices and their differences at the carcass, slaughter, and feeder market levels. The quarterly econometric model utilized rational distributed lags to incorporate the dynamic relationships inherent in the industry. Ultimately, price flexibilities for various quarterly time periods were calculated to determine the impact of the economic variables. The process involved testing the significance of the independent variables for each gender at each market level. These variables served as the base to then directly estimate the impact of independent variables on the price premium between steers and heifers.

Overall, the behavioral model revealed dynamic relationships of a geometric nature. The adjustment periods for the dependent price variables were fairly short, usually stabilizing within four to six quarters. In addition, on a quarterly basis, the price structure of the cattle industry can be described as a system (recursive framework). Thus, estimating price behavior without a system specification may have serious shortcomings. The importance of marketing margins are manifested when interfacing the different market levels.

Steer and heifer carcass prices were estimated as a function of quantity of steer and heifer carcasses, quantity of substitutes, by-product values, disposable income, and the marketing margin. The inverse demand equations were estimated as first-order nonstochastic difference equations. All right hand side variables were predetermined with the exception of the marketing margin as the latter was considered jointly dependent with retail and carcass prices.

Initially these variables were incorporated into equations measuring the difference between steer and heifer carcass prices. Statistical tests indicated that steer and heifer carcass supply was the only variable that accounted for the systematic part of the difference, i.e., as quantity increased the difference increased. Examination of the data revealed that there was very little variation in the price difference at the wholesale level. Given quality differences in steer and heifer carcasses, and little explanation by carcass supply, as indicated by the low adjusted R^2 statistic, it appears a large proportion of the variation is due to random factors which include uncertainty, lack of information, and formula pricing.

Slaughter steer and heifer prices were estimated as static functions. The independent regressors included steer carcass price, fed and nonfed steer and heifer slaughter, and by-product value. The static functions, as compared to dynamic functions in the carcass market, were not too surprising since packers adjust rapidly due to the perishable nature of the product, limited storage and handling capabilities, and the nature of the formula pricing.

As with the steer-heifer carcass price difference, variation in the slaughter steer-heifer price premium was relatively small. Steer carcass price had a positive impact on the slaughter price difference, indicating that as prices in the carcass trade were increasing there was a tendency to bid relatively more for the better quality steer. This appeared, however, to merely reflect the value of the steer carcass price premium.

The price equations for the feeder market were estimated as first order nonstochastic difference equations with positive serial correlation. Current, as well as past values of the numbers of steers and heifers on feed, corn prices, marketing margin, and slaughter steer price determined feeder cattle prices. The difference equation parameters of the geometric functions were small indicating that the adjustment process in the cattle feeding industry is relatively rapid and thus marketing and placements tend to be current.

Feeder steer-heifer price premiums were also estimated as dynamic first order difference equations with positive serial correlation. The light cattle price difference (400-500 lbs.) was influenced by slaughter steer price and quantities of steers and heifers on feed. The heavier cattle price difference (600-700 lbs.) was determined by these same variables plus the price of corn. For both weight categories of cattle, the price premium of steers increased as slaughter steer price and quantity of heifers on feed increased, while increases in the quantity of steers on feed decreased the steer price premium relationship. Corn price apparently had little measurable impact on the light cattle price difference, however, the heavier cattle price difference was positively correlated with changes in corn price. This result suggests that when corn price increases. (1) cattle feeders make a relative shift away from feeding lighter to feeding heavier cattle, and (2) cattle feeders adjust the relative input prices between sexes of heavier feeders to account for feed conversion efficiency.

Several concluding remarks are in order. First, the study did not deal with the pricing of fabricated boxed beef. For the past several years the carcass trade relative to the boxed beef trade has been declining in importance. However, the variation in prices of subprimal cuts makes it difficult to relate the wholesale sector back to the slaughter and feeder levels; on the other hand the carcass trade facilitates this interface. Second, further integration into processing and distribution by packers could alter the estimated behavioral equations due to the change in nature of pricing at this level. Third, alternative approaches to determining the factors that influence steer-heifer price differences may exist. The development or improvement of statistical tests of parameter estimates derived from direct subtraction of the behavioral equations would serve as a comparison measure. Finally, the results of this study should be interpreted in view of the fact that perfect competition is not the actual market structure characterized by the beef industry. That is, institutional constraints such as formula pricing, regional market concentration, and different buying and selling strategies may indicate that regional responses are different.

LITERATURE CITED

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Boggs, D. L., and Merkel, R. A. *Live Animal Carcass Evaluation and Selection Manual.* Dubuque: Kendall-Hunt Publishing Co., 1979, pp. 69-79.

Brester, G. W. "A Dynamic Price and Supply Model of the U.S. Beef Industry: An Interfacing of the Market Levels." Unpublished M.S. Thesis, Montana State University, Bozeman. April 1982.

Brester, G. W., and Marsh, J. M. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." *Western J. Agr. Econ.* 8 (July 1983)¾ 34-49.

Buccola, S. T. "An Approach to the Analysis of Feeder Cattle Price Differentials." *Amer. J. Agr. Econ.* 62 (August 1980): 574-580.

Buccola, S. T., and Jessee, D. L. "An U.S. Regional Model of Feeder Steer-Heifer Price Differentials." *Southern J. Agr. Econ.* 11 (July 1979): 61-65.

Burt, O. R. "Nonstochastic Difference Equations, Distributed Lags, and Agricultural Supply." Dept. Agr. Econ. and Econ. Staff Pap. No. 78-9. Montana State University, Bozeman. October 1978.

Burt, O. R. "Estimation of Distributed Lags as Nonstochastic Difference Equations." Dept. Agr. Econ. and Econ. Staff Pap. No. 80-1. Montana State University, Bozeman. January 1980.

Burt, O. R., and Townsend, S. "Instructional Manual for DYNREG—A Nonlinear Least Squares Algorithm for Distributed Lag Models and/or Regression Models with Time Series Error Terms." Montana State University, Bozeman. November 1980. (Mimeographed).

Freebairn, J. W., and Rausser, G. C. "Effects of Changes in the Level of U.S. Beef Imports." *Amer. J. Agr. Econ.* 57 (November 1975): 676-688.

Jorgenson, D. W. "Rational Distributed Lag Functions." *Econometrica* 32 (January 1966): 135-149.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971, pp. 487-491.

Lambert, C., Corah, L., and Grunewald, O. "Factors Affecting Prices of Calves and Yearlings in Kansas." Ag Fact Sheet MF-667. Kansas State University, Manhattan. November 1981.

Marsh, J. M. "A Rational Distributed Lag Model of Quarterly Live Cattle Prices." *Amer. J. Agr. Econ.* 65 (August 1983): 539-547.

Marsh, J. M. "Monthly Price Premiums and Discounts Between Steer Calves and Yearlings." Montana State University, Bozeman. October 1983. (Mimeographed).

Riley, J. "A Look at Ways to Handle Pregnancy in the Feedlot." *BEEF*, April 1983, p. 9.

Tomek, W. G., and Robinson, K. L. *Agricultural Product Prices*. 2nd ed. Ithaca: Cornell University Press, 1981. pp. 38-42.

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

Wold, H., and Jureen, L. *Demand Analysis*. New York: John Wiley and Sons, 1953, pp. 60-70.

Wonnacott, R. J., and Wonnacott, T. H. *Econometrics*. 2nd ed. New York: John Wiley and Sons, 1979. pp. 225-226.

APPENDIX

Table 9. Original Data Used in the Multi Market Steer and Heifer Equations.

OBS	Slaughter Steer Price	Slaughter Heifer Price	Steer Carcass Price	Heifer Carcass Price	Original Quantity Feeder Steers	Original Quantity Feeder Heifers	Quantity Steer Carcasses	Quantity Heifer Carcasses
1	.29370E+02	.28440E+02	.47170E+02	.46290E+02	.73220E+04	.32990E+04	.31660E+04	.13220E+04
2	.29890E+02	.29190E+02	.47530E+02	.46990E+02	.68290E+04	.29570E+04	.33260E+04	.12540E+04
3	.29870E+02	.29010E+02	.48140E+02	.46940E+02	.63320E+04	.28950E+04	.32000E+04	.14320E+04
4	.27040E+02	.26140E+02	.43970E+02	.42370E+02	.65190E+04	.26090E+04	.32220E+04	.14250E+04
5	.30370E+02	.29680E+02	.49880E+02	.48630E+02	.74180E+04	.29120E+04	.32180E+04	.12780E+04
6	.32220E+02	.31600E+02	.52350E+02	.51480E+02	.70070E+04	.29810E+04	.33630E+04	.12440E+04
7	.32300E+02	.31430E+02	.52350E+02	.51090E+02	.67140E+04	.28240E+04	.32870E+04	.14490E+04
8	.33070E+02	.32130E+02	.52980E+02	.51890E+02	.67390E+04	.26000E+04	.31970E+04	.13060E+04
9	.35380E+02	.34380E+02	.56030E+02	.55140E+02	.79070E+04	.34130E+04	.32890E+04	.12410E+04
10	.35850E+02	.34830E+02	.55660E+02	.54430E+02	.76900E+04	.33210E+04	.34630E+04	.12900E+04
11	.35960E+02	.34640E+02	.54870E+02	.50200E+02	.76740E+04	.32660E+04	.32750E+04	.14570E+04
12	.34760E+02	.33710E+02	.52840E+02	.51320E+02	.75100E+04	.29410E+04	.34010E+04	.14910E+04
13	.44110E+02	.41890E+02	.65810E+02	.64650E+02	.85200E+04	.34310E+04	.32720E+04	.12050E+04
14	.45560E+02	.41330E+02	.69460E+02	.68420E+02	.82480E+04	.33170E+04	.31260E+04	.11800E+04
15	.48210E+02	.46690E+02	.71000E+02	.69600E+02	.79650E+04	.32800E+04	.29400E+04	.12140E+04
16	.39420E+02	.38310E+02	.65590E+02	.62160E+02	.78740E+04	.28860E+04	.33300E+04	.14190E+04
17	.44480E+02	.43490E+02	.72020E+02	.70800E+02	.82630E+04	.30320E+04	.33230E+04	.11920E+04
18	.39510E+02	.38680E+02	.64170E+02	.62890E+02	.78610E+04	.27960E+04	.36580E+04	.12250E+04
19	.43700E+02	.42300E+02	.70460E+02	.68970E+02	.63910E+04	.23710E+04	.33940E+04	.13420E+04
20	.37570E+02	.36480E+02	.61950E+02	.60550E+02	.58730E+04	.21390E+04	.33480E+04	.13900E+04
21	.35360E+02	.34240E+02	.59070E+02	.57800E+02	.57830E+04	.23170E+04	.33360E+04	.13520E+04
22	.47910E+02	.45640E+02	.77820E+02	.76440E+02	.50140E+04	.21160E+04	.30310E+04	.13080E+04
23	.48460E+02	.46130E+02	.79380E+02	.77460E+02	.49130E+04	.24890E+04	.28610E+04	.14980E+04
24	.45730E+02	.43910E+02	.74040E+02	.72050E+02	.55180E+04	.26540E+04	.27580E+04	.16490E+04
25	.38210E+02	.36900E+02	.61960E+02	.60330E+02	.70560E+04	.35070E+04	.32210E+04	.18500E+04
26	.40940E+02	.39500E+02	.63950E+02	.63030E+02	.62620E+04	.31340E+04	.32370E+04	.16780E+04
27	.36800E+02	.35770E+02	.57500E+02	.56580E+02	.57620E+04	.30650E+04	.33330E+04	.17490E+04
28	.38570E+02	.37380E+02	.60580E+02	.59090E+02	.50970E+04	.30390E+04	.31630E+04	.17700E+04
29	.37760E+02	.36340E+02	.58690E+02	.57350E+02	.65890E+04	.36400E+04	.32520E+04	.17380E+04
30	.40400E+02	.39040E+02	.62530E+02	.61160E+02	.60020E+04	.31200E+04	.34580E+04	.16090E+04
31	.39990E+02	.38460E+02	.62960E+02	.61340E+02	.55550E+04	.29990E+04	.33510E+04	.17560E+04
32	.41420E+02	.40610E+02	.66290E+02	.64560E+02	.55010E+04	.30940E+04	.31580E+04	.16970E+04
33	.45070E+02	.43850E+02	.71570E+02	.69820E+02	.71930E+04	.39060E+04	.32420E+04	.16460E+04
34	.54920E+02	.53370E+02	.85340E+02	.80650E+02	.64290E+04	.38320E+04	.31820E+04	.16130E+04
35	.53220E+02	.51730E+02	.82980E+02	.80180E+02	.60790E+04	.36570E+04	.30550E+04	.18210E+04
36	.54570E+02	.53370E+02	.82620E+02	.80300E+02	.67210E+04	.35050E+04	.31920E+04	.17780E+04
37	.64880E+02	.64160E+02	.97710E+02	.96140E+02	.74870E+04	.36840E+04	.32070E+04	.14820E+04
38	.72470E+02	.71550E+02	.10691E+03	.10590E+03	.64470E+04	.33190E+04	.29920E+04	.13230E+04
39	.65630E+02	.64170E+02	.98630E+02	.96570E+02	.60750E+04	.31440E+04	.29500E+04	.15140E+04
40	.66870E+02	.65630E+02	.10204E+03	.10037E+03	.59870E+04	.29490E+04	.30030E+04	.15060E+04
41	.67100E+02	.65990E+02	.10304E+03	.10217E+03	.69550E+04	.33420E+04	.31010E+04	.13160E+04
42	.64730E+02	.63220E+02	.10246E+03	.99980E+02	.60100E+04	.30010E+04	.30840E+04	.13740E+04
43	.71190E+02	.68140E+02	.10985E+03	.10620E+03	.56070E+04	.29860E+04	.29340E+04	.15480E+04
44	.65830E+02	.63860E+02	.10253E+03	.99900E+02	.61340E+04	.28120E+04	.30240E+04	.15580E+04
45	.62240E+02	.60660E+02	.96880E+02	.95010E+02	.65770E+04	.32100E+04	.32050E+04	.14730E+04
46	.66740E+02	.65150E+02	.10313E+03	.10134E+03	.58000E+04	.28260E+04	.31290E+04	.14230E+04
47	.66630E+02	.64740E+02	.10469E+03	.10137E+03	.55580E+04	.30490E+04	.29790E+04	.16180E+04
48	.60420E+02	.59080E+02	.94760E+02	.92690E+02	.55800E+04	.26090E+04	.30330E+04	.16320E+04
49	.64070E+02	.62700E+02	.10026E+03	.98400E+02	.62070E+04	.27710E+04	.29190E+04	.13230E+04
50	.71240E+02	.69570E+02	.11162E+03	.10963E+03	.56680E+04	.31110E+04	.28550E+04	.13140E+04
51	.64480E+02	.62850E+02	.10027E+03	.98650E+02	.56430E+04	.33060E+04	.28480E+04	.16440E+04
52	.58980E+02	.57710E+02	.92610E+02	.91060E+02	.56000E+04	.31750E+04	.27730E+04	.16480E+04

[a] Observations 1-52 represent years 1970-1982.

Table 9 (continued).

OBS	Population	Price of Feeder Steers 400-500 lb	Price of Feeder Steers 600-700 lb	Price of Feeder Heifers 400-500 lb	Price of Feeder Heifers 600-700 lb	Original Farm-Carcass Margin	Original Carcass-Retail Margin	Quantity of Fed Slaughter
1	.20080E+01	.38370E+02	.34370E+02	.33190E+02	.30580E+02	.63000E+01	.30700E+02	.63320E+04
2	.20150E+01	.40500E+02	.34980E+02	.35510E+02	.31750E+02	.50000E+01	.31400E+02	.54060E+04
3	.20230E+01	.39800E+02	.34540E+02	.34130E+02	.30500E+02	.60000E+01	.31200E+02	.64910E+04
4	.20310E+01	.36390E+02	.31870E+02	.31590E+02	.28330E+02	.61000E+01	.34100E+02	.54010E+04
5	.20380E+01	.37610E+02	.33650E+02	.32910E+02	.30010E+02	.72000E+01	.29200E+02	.54180E+04
6	.20450E+01	.38990E+02	.34520E+02	.33150E+02	.30770E+02	.73000E+01	.30600E+02	.64660E+04
7	.20520E+01	.39260E+02	.34830E+02	.34030E+02	.31620E+02	.65000E+01	.31600E+02	.57920E+04
8	.20600E+01	.41150E+02	.36570E+02	.35330E+02	.32980E+02	.66000E+01	.31600E+02	.63630E+04
9	.20660E+01	.43380E+02	.38470E+02	.36650E+02	.34330E+02	.66000E+01	.35600E+02	.56270E+04
10	.20720E+01	.46380E+02	.40300E+02	.39680E+02	.35970E+02	.66000E+01	.33800E+02	.59290E+04
11	.20780E+01	.48040E+02	.42460E+02	.41830E+02	.38560E+02	.61000E+01	.38400E+02	.71140E+04
12	.20830E+01	.49360E+02	.44360E+02	.42460E+02	.39320E+02	.65000E+01	.38700E+02	.69780E+04
13	.20880E+01	.56920E+02	.50770E+02	.48380E+02	.44220E+02	.63000E+01	.37700E+02	.57790E+04
14	.20930E+01	.61810E+02	.53830E+02	.53130E+02	.47780E+02	.57000E+01	.39800E+02	.54720E+04
15	.20990E+01	.66570E+02	.57980E+02	.56560E+02	.51600E+02	.42000E+01	.40700E+02	.61370E+04
16	.21040E+01	.56160E+02	.50200E+02	.48020E+02	.44520E+02	.95000E+01	.47600E+02	.66690E+04
17	.21090E+01	.54380E+02	.47780E+02	.45970E+02	.42630E+02	.94000E+01	.45900E+02	.51780E+04
18	.21140E+01	.45050E+02	.39800E+02	.39110E+02	.35980E+02	.93000E+01	.45700E+02	.64580E+04
19	.21190E+01	.35650E+02	.34640E+02	.31810E+02	.31090E+02	.79000E+01	.44100E+02	.57030E+04
20	.21250E+01	.28110E+02	.29310E+02	.23260E+02	.24910E+02	.82000E+01	.49500E+02	.57050E+04
21	.21300E+01	.26990E+02	.27390E+02	.22180E+02	.23390E+02	.90000E+01	.48200E+02	.56720E+04
22	.21350E+01	.33980E+02	.34670E+02	.26480E+02	.29570E+02	.86000E+01	.38900E+02	.51750E+04
23	.21410E+01	.33140E+02	.35540E+02	.27220E+02	.29900E+02	.10900E+02	.47600E+02	.51700E+04
24	.21470E+01	.36080E+02	.38060E+02	.27500E+02	.31300E+02	.88000E+01	.51600E+02	.50990E+04
25	.21520E+01	.40960E+02	.39190E+02	.32230E+02	.32860E+02	.87000E+01	.58600E+02	.65350E+04
26	.21570E+01	.46470E+02	.43890E+02	.38140E+02	.37850E+02	.68000E+01	.55000E+02	.61190E+04
27	.21620E+01	.39980E+02	.38100E+02	.33340E+02	.33430E+02	.69000E+01	.58900E+02	.63860E+04
28	.21680E+01	.38830E+02	.36400E+02	.31010E+02	.31490E+02	.71000E+01	.54500E+02	.58550E+04
29	.21730E+01	.41350E+02	.37770E+02	.32710E+02	.33000E+02	.85000E+01	.56400E+02	.66560E+04
30	.21780E+01	.44460E+02	.41100E+02	.35860E+02	.35790E+02	.66000E+01	.52800E+02	.63310E+04
31	.21840E+01	.45160E+02	.41160E+02	.37150E+02	.36530E+02	.82000E+01	.55100E+02	.53440E+04
32	.21900E+01	.43760E+02	.40700E+02	.35710E+02	.36140E+02	.89000E+01	.54000E+02	.62680E+04
33	.21960E+01	.51860E+02	.47890E+02	.43420E+02	.42600E+02	.86000E+01	.56300E+02	.69840E+04
34	.22020E+01	.65420E+02	.58000E+02	.54920E+02	.52280E+02	.73000E+01	.58800E+02	.58200E+04
35	.22080E+01	.71510E+02	.62710E+02	.60790E+02	.57010E+02	.88000E+01	.67500E+02	.67190E+04
36	.22150E+01	.74530E+02	.66520E+02	.64270E+02	.59010E+02	.83000E+01	.67600E+02	.59420E+04
37	.22210E+01	.93640E+02	.80930E+02	.80840E+02	.71380E+02	.88000E+01	.69300E+02	.69490E+04
38	.22270E+01	.10289E+03	.86830E+02	.87670E+02	.76660E+02	.94000E+01	.77800E+02	.63300E+04
39	.22330E+01	.10047E+03	.82500E+02	.83150E+02	.72710E+02	.10200E+02	.79900E+02	.51550E+04
40	.22400E+01	.93620E+02	.82180E+02	.78350E+02	.71750E+02	.10800E+02	.75900E+02	.59290E+04
41	.22460E+01	.93370E+02	.80440E+02	.78790E+02	.71390E+02	.10400E+02	.81600E+02	.63290E+04
42	.22520E+01	.81550E+02	.70430E+02	.67430E+02	.61580E+02	.10000E+02	.79100E+02	.57990E+04
43	.22590E+01	.82890E+02	.75770E+02	.70230E+02	.66370E+02	.10000E+02	.78700E+02	.59030E+04
44	.22650E+01	.80760E+02	.74260E+02	.68290E+02	.65830E+02	.11400E+02	.89500E+02	.58470E+04
45	.22690E+01	.77470E+02	.70590E+02	.65290E+02	.63190E+02	.11300E+02	.92100E+02	.51940E+04
46	.22740E+01	.73990E+02	.66620E+02	.62150E+02	.60270E+02	.92000E+01	.81300E+02	.57690E+04
47	.22800E+01	.70500E+02	.65040E+02	.59680E+02	.59050E+02	.11500E+02	.87100E+02	.51290E+04
48	.22860E+01	.65590E+02	.62720E+02	.54420E+02	.54990E+02	.11300E+02	.97100E+02	.56120E+04
49	.22910E+01	.66610E+02	.63050E+02	.54770E+02	.56030E+02	.11100E+02	.87400E+02	.51510E+04
50	.22960E+01	.70830E+02	.66480E+02	.58860E+02	.59030E+02	.10200E+02	.81700E+02	.58860E+04
51	.23020E+01	.69450E+02	.66530E+02	.59560E+02	.59760E+02	.95000E+01	.99700E+02	.65230E+04
52	.23080E+01	.66430E+02	.63230E+02	.55070E+02	.56880E+02	.99000E+01	.98400E+02	.50840E+04

Table 9 (continued).

OBS	Quantity of Nonfed Slaughter	Predicted Quantity of Feeder Steers	Predicted Quantity of Feeder Heifers	Predicted Carcass-Retail Margin	Predicted Farm-Carcass Margin	Corn Price	Predicted Steer Carcass Price	Predicted Slaughter Steer Price
1	.55000E+03	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
2	.69000E+03	.35440E+04	.13660E+04	.26510E+02	.00000E+00	.00000E+00	.00000E+00	.00000E+00
3	.75300E+03	.32670E+04	.13800E+04	.27600E+02	.52400E+01	.00000E+00	.00000E+00	.00000E+00
4	.70900E+03	.32300E+04	.13050E+04	.28910E+02	.55600E+01	.00000E+00	.00000E+00	.00000E+00
5	.53700E+03	.36390E+04	.14050E+04	.25190E+02	.58400E+01	.12400E+01	.41620E+02	.25520E+02
6	.69900E+03	.34360E+04	.14170E+04	.24840E+02	.57700E+01	.12500E+01	.43610E+02	.26830E+02
7	.69200E+03	.32450E+04	.14170E+04	.26510E+02	.53400E+01	.12400E+01	.42160E+02	.25880E+02
8	.61000E+03	.32070E+04	.13270E+04	.25620E+02	.51700E+01	.13700E+01	.44210E+02	.27000E+02
9	.40600E+03	.37640E+04	.15360E+04	.28180E+02	.59400E+01	.15100E+01	.44760E+02	.27840E+02
10	.45100E+03	.36300E+04	.15690E+04	.28160E+02	.54200E+01	.18700E+01	.44340E+02	.28240E+02
11	.24700E+03	.36100E+04	.16190E+04	.29690E+02	.44000E+01	.24700E+01	.43090E+02	.28110E+02
12	.38600E+03	.37220E+04	.15450E+04	.31550E+02	.47300E+01	.24100E+01	.41200E+02	.27090E+02
13	.13700E+03	.39810E+04	.15900E+04	.27440E+02	.50000E+01	.28100E+01	.49800E+02	.32290E+02
14	.85000E+02	.37900E+04	.15990E+04	.29390E+02	.45100E+01	.25600E+01	.53560E+02	.34910E+02
15	.14500E+03	.37150E+04	.14640E+04	.31780E+02	.45400E+01	.34000E+01	.54680E+02	.35990E+02
16	.34000E+03	.39140E+04	.14530E+04	.34920E+02	.60900E+01	.34800E+01	.46710E+02	.30180E+02
17	.48600E+03	.38160E+04	.14010E+04	.31700E+02	.62700E+01	.28100E+01	.49910E+02	.31990E+02
18	.78700E+03	.36110E+04	.13860E+04	.31000E+02	.59200E+01	.25600E+01	.45740E+02	.28670E+02
19	.15040E+04	.29140E+04	.10990E+04	.30200E+02	.52900E+01	.34000E+01	.45680E+02	.28510E+02
20	.16650E+04	.28040E+04	.10140E+04	.30720E+02	.58600E+01	.34800E+01	.41430E+02	.25050E+02
21	.16300E+04	.29940E+04	.12990E+04	.30840E+02	.54400E+01	.28700E+01	.39200E+02	.23520E+02
22	.16820E+04	.25570E+04	.11410E+04	.24370E+02	.50600E+01	.28300E+01	.48740E+02	.29760E+02
23	.19330E+04	.23940E+04	.11280E+04	.29960E+02	.57800E+01	.30000E+01	.47390E+02	.29110E+02
24	.18990E+04	.23800E+04	.11280E+04	.31580E+02	.57300E+01	.26200E+01	.44390E+02	.27130E+02
25	.13890E+04	.31180E+04	.16030E+04	.34280E+02	.55100E+01	.26000E+01	.37950E+02	.23300E+02
26	.14630E+04	.27730E+04	.14320E+04	.31650E+02	.38500E+01	.27300E+01	.37990E+02	.24170E+02
27	.16500E+04	.25190E+04	.13790E+04	.32790E+02	.43700E+01	.27000E+01	.33500E+02	.21230E+02
28	.16450E+04	.23550E+04	.13220E+04	.31530E+02	.40600E+01	.22800E+01	.33470E+02	.20990E+02
29	.10650E+04	.31230E+04	.15710E+04	.32620E+02	.47600E+01	.23700E+01	.32830E+02	.21210E+02
30	.14720E+04	.28100E+04	.14930E+04	.30670E+02	.44500E+01	.22000E+01	.34100E+02	.22090E+02
31	.16400E+04	.24820E+04	.14460E+04	.29640E+02	.45600E+01	.17400E+01	.35570E+02	.22540E+02
32	.13080E+04	.25390E+04	.13810E+04	.30350E+02	.45400E+01	.19500E+01	.36810E+02	.23170E+02
33	.72300E+03	.31770E+04	.17360E+04	.31630E+02	.44800E+01	.20600E+01	.38750E+02	.24680E+02
34	.69800E+03	.29960F+04	.16650E+04	.30190E+02	.38000E+01	.23100E+01	.42160E+02	.27120E+02
35	.82500E+03	.28610E+04	.16630E+04	.32370E+02	.38200E+01	.20200E+01	.42680E+02	.27830E+02
36	.57200E+03	.31260E+04	.15770E+04	.33230E+02	.47000E+01	.20600E+01	.42340E+02	.27620E+02
37	.23500E+03	.34260E+04	.16890E+04	.34470E+02	.43900E+01	.21400E+01	.45750E+02	.30580E+02
38	.19700E+03	.29670E+04	.15650E+04	.35620E+02	.38100E+01	.24200E+01	.49530E+02	.34220E+02
39	.58900E+03	.27910E+04	.14270E+04	.36800E+02	.47600E+01	.25000E+01	.45770E+02	.30800E+02
40	.73600E+03	.27120E+04	.12690E+04	.33480E+02	.49800E+01	.23500E+01	.44630E+02	.28750E+02
41	.19900E+03	.31630E+04	.15150E+04	.34600E+02	.42300E+01	.22700E+01	.43380E+02	.28130E+02
42	.84500E+03	.26590E+04	.12710E+04	.31930E+02	.42300E+01	.24200E+01	.41330E+02	.26190E+02
43	.90400E+03	.25330E+04	.12870E+04	.31080E+02	.38600E+01	.29300E+01	.42940E+02	.27790E+02
44	.91900E+03	.25510E+04	.12270E+04	.34550E+02	.43100E+01	.32700E+01	.39660E+02	.25600E+02
45	.63500E+03	.29600E+04	.14370E+04	.35180E+02	.42600E+01	.32100E+01	.37180E+02	.23950E+02
46	.98900E+03	.25390E+04	.12070E+04	.31970E+02	.37900E+01	.32200E+01	.37700E+02	.24340E+02
47	.87100E+03	.24220E+04	.12890E+04	.31890E+02	.38100E+01	.28200E+01	.36830E+02	.23790E+02
48	.13110E+04	.23100E+04	.11640E+04	.33000E+02	.43300E+01	.24000E+01	.34080E+02	.21590E+02
49	.60700E+03	.26800E+04	.13200E+04	.30260E+02	.39400E+01	.24700E+01	.36880E+02	.23410E+02
50	.85600E+03	.23830E+04	.13620E+04	.28770E+02	.37400E+01	.26400E+01	.40390E+02	.25570E+02
51	.67600E+03	.24990E+04	.15200E+04	.33320E+02	.35700E+01	.23300E+01	.35210E+02	.22670E+02
52	.87200E+03	.24590E+04	.13330E+04	.33830E+02	.27200E+01	.22800E+01	.29670E+02	.19100E+02

Table 9 (continued).

OBS	Quantity Pork	Quantity Poultry	Consumer Price Index	Per Capita Disposable Income	Price of Farm By-product	Price of Carcass By-product
1	.33420E+04	.18000E+04	.11390E+01	.32610E+04	.66000E+01	.13000E+01
2	.34210E+04	.20350E+04	.11570E+01	.33420E+04	.65000E+01	.13000E+01
3	.34500E+04	.20200E+04	.11700E+01	.33780E+04	.62000E+01	.13000E+01
4	.42870E+04	.18320E+04	.11860E+01	.33890E+04	.60000E+01	.12000E+01
5	.40100E+04	.18140E+04	.11950E+01	.34670E+04	.59000E+01	.14000E+01
6	.39870E+04	.19580E+04	.12080E+01	.35830E+04	.64000E+01	.14000E+01
7	.37240E+04	.20410E+04	.12200E+01	.36140E+04	.61000E+01	.14000E+01
8	.40940E+04	.19100E+04	.12270E+01	.36330E+04	.64000E+01	.15000E+01
9	.37100E+04	.19420E+04	.12370E+01	.36700E+04	.75000E+01	.15000E+01
10	.36230E+04	.21370E+04	.12470E+01	.37510E+04	.90000E+01	.15000E+01
11	.32370E+04	.20950E+04	.12580E+01	.38210E+04	.10000E+02	.15000E+01
12	.36710E+04	.19730E+04	.12680E+01	.39540E+04	.11100E+02	.15000E+01
13	.33850E+04	.19110E+04	.12870E+01	.41290E+04	.11900E+02	.18000E+01
14	.33280E+04	.20480E+04	.13150E+01	.42420E+04	.12800E+02	.19000E+01
15	.28690E+04	.20480E+04	.13440E+01	.43400E+04	.14000E+02	.20000E+01
16	.34610E+04	.20250E+04	.13760E+01	.44530E+04	.11900E+02	.17000E+01
17	.34810E+04	.20090E+04	.14140E+01	.45130E+04	.12200E+02	.20000E+01
18	.36700E+04	.21600E+04	.14540E+01	.45740E+04	.97000E+01	.18000E+01
19	.33810E+04	.21100E+04	.14990E+01	.46970E+04	.10400E+02	.19000E+01
20	.35680E+04	.18490E+04	.15420E+01	.47790E+04	.84000E+01	.17000E+01
21	.31420E+04	.18600E+04	.15700E+01	.48080E+04	.72000E+01	.16000E+01
22	.29920E+04	.20920E+04	.15950E+01	.50700E+04	.98000E+01	.21000E+01
23	.25550E+04	.21100E+04	.16290E+01	.51050E+04	.10700E+02	.22000E+01
24	.28960E+04	.20210E+04	.16550E+01	.52270E+04	.10500E+02	.20000E+01
25	.29580E+04	.21470E+04	.16710E+01	.53470E+04	.94000E+01	.17000E+01
26	.28470E+04	.23320E+04	.16920E+01	.54550E+04	.11500E+02	.17000E+01
27	.30140E+04	.24040E+04	.17190E+01	.55260E+04	.10400E+02	.16000E+01
28	.36690E+04	.22030E+04	.17380E+01	.56370E+04	.10200E+02	.17000E+01
29	.32940E+04	.22000E+04	.17690E+01	.57630E+04	.11500E+02	.17000E+01
30	.31850E+04	.24160E+04	.18050E+01	.59360E+04	.12500E+02	.19000E+01
31	.30730E+04	.24730E+04	.18330E+01	.60940E+04	.11600E+02	.21000E+01
32	.35000E+04	.22950E+04	.18530E+01	.62560E+04	.11700E+02	.19000E+01
33	.32430E+04	.23740E+04	.18850E+01	.64010E+04	.12600E+02	.20000E+01
34	.32650E+04	.25980E+04	.19340E+01	.65830E+04	.14200E+02	.22000E+01
35	.31600E+04	.26190E+04	.19790E+01	.67480E+04	.16200E+02	.24000E+01
36	.35410E+04	.24930E+04	.20190E+01	.69540E+04	.17200E+02	.24000E+01
37	.33950E+04	.26160E+04	.20690E+01	.70490E+04	.21100E+02	.27000E+01
38	.37540E+04	.29140E+04	.21410E+01	.71760E+04	.27000E+02	.31000E+01
39	.37750E+04	.30050E+04	.22120E+01	.73810E+04	.22300E+02	.27000E+01
40	.43460E+04	.27320E+04	.22770E+01	.75630E+04	.17900E+02	.26000E+01
41	.41250E+04	.27780E+04	.23660E+01	.77930E+04	.17200E+02	.22000E+01
42	.42990E+04	.30160E+04	.24520E+01	.78340E+04	.14200E+02	.21000E+01
43	.37560E+04	.28100E+04	.24980E+01	.80950E+04	.18200E+02	.25000E+01
44	.42520E+04	.27520E+04	.25620E+01	.83250E+04	.18100E+02	.23000E+01
45	.40730E+04	.28700E+04	.26290E+01	.85510E+04	.16000E+02	.20000E+01
46	.38810E+04	.31150E+04	.26900E+01	.86980E+04	.16600E+02	.21000E+01
47	.36050E+04	.31000E+04	.27670E+01	.89510E+04	.16300E+02	.23000E+01
48	.41570E+04	.28970E+04	.28070E+01	.91070E+04	.15200E+02	.21000E+01
49	.36950E+04	.29070E+04	.28300E+01	.91550E+04	.14700E+02	.20000E+01
50	.35500E+04	.31200E+04	.28730E+01	.92850E+04	.15900E+02	.25000E+01
51	.30660E+04	.31580E+04	.29250E+01	.94610E+04	.15400E+02	.21000E+01
52	.34510E+04	.29470E+04	.29340E+01	.95460E+04	.13900E+02	.12000E+01