Derived Demand for Cattle Feeding Inputs

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Abstract

Derived demand relationships among four weight categories of feeder cattle entering Texas feedlots and feed were examined using a Generalized McFadden dual cost function specified as an error correction model. Relationships among own- and cross-price elasticities provide evidence for at least two cattle feeding enterprises, feeding lightweight feeder cattle (calves) and feeding heavier cattle. These results indicate systematic differences in demand relationships among the different weight classes, providing explanation and insight into mixed results from earlier studies. Seasonality differed across weight categories, providing additional support for multiple cattle feeding enterprises. A third step was added to the Engle-Granger two-step estimation procedure to incorporate information provided in the second step.

Introduction

Feeder cattle are kept on pasture or some other relatively high-roughage sustenance until they are placed in feedlots. Conventional wisdom characterizes the decision to place them in feedlots depending on a variety of factors, including relative prices of various weights of feeder cattle, feed prices, and other factors. While many aspects of feeder cattle price differentials have been explained, empirical research results on this issue have been mixed. Generally, feeder cattle models have not been specified in ways amenable to explaining all of the relationships that underlie reported average placement weights and price-weight relationships. This paper extends earlier research by explicitly examining feeder cattle demand by weight category.

The research is motivated by three problems: First, many cattle feeding models consider only one optimal cattle feeding activity. Placement weight is either fixed or the optimal placement weight is determined for a single feeding activity, given a set of prices for cattle and/or feed (Anderson and Trapp; Buccola; Dhuyvetter and Schroeder; Lambert et al.; Mark, Schroeder, and Jones; Marsh). By disallowing solutions with multiple cattle feeding enterprises, these specifications preclude capturing links between demonstrated feeding regimes (Brewer et al. and Jordan et al.).

Second, data on which previous research was based often lacked sufficient detail, or modelers failed to exploit the detail that existed, to discern inter-weight-class relationships in feeder cattle placements. For example, average feedlot closeout data obscures details of a number of underlying factors (e.g., Hoelscher in *FeedStuffs*), including data on placement weights and days fed. Third, systematic explanation of weight price relationships is often lacking for the mixed results reported across previous studies. Prominent in the literature is the logic that higher feed prices favor heavier weight placements, which will be on feed for shorter periods and, thus, eat less high-priced feed (Dhuyvetter and Schroeder; Anderson and Trapp). However, some studies report opposite results (Marsh).

This paper highlights differences in demand relationships among different weight classes of feeder cattle placements and provides a rationale for the mixed feed/feeder cattle demand relationships found in previous studies. The objectives of this paper are: (1) explore the likelihood of multiple cattle feeding enterprises; (2) examine the implications of multiple feeding enterprises on demand for feed and feeder cattle of different weights; (3) examine seasonal components of feeder cattle placement by

weights. To meet these objectives, a Generalized McFadden cost function is specified and estimated as an error correction model (ECM).

We introduce several innovations: First, we disaggregate feedlot placements into four weight subgroups and examine tradeoffs between feed and weight categories. Second, feed is decomposed and priced as energy and protein, allowing for parsimony in the model and allowing us to test for fixed proportions between energy and protein. Third, we add a third step to the Engle-Granger two-step ECM estimation procedure that allows us to improve our parameter estimates.

Feeder Cattle Demand and Average Weights of Cattle Entering Feedlots

The significance of factors affecting the price-weight relationships of feeder cattle and calves has been reported in several studies (Anderson and Trapp; Buccola; Dhuyvetter and Schroeder; Lambert et al.; Schroeder, and Jones; Marsh). The literature characterizing price-weight relationships for feeder cattle originates from two primary analytical perspectives. One approach exploits feeder cattle price-weight relationships to determine an optimal feeder cattle placement weight that maximizes cattle feeding profits or minimizes cattle feeding costs. The second approach is based on the analysis of factors that affect price differentials in feeder cattle markets.

While addressing general price-weight relationships in feeder cattle prices, these studies have not addressed the relationships between weight classes. Reported relationships between feeder cattle prices and weights appear mixed across studies. For example, Lambert et al. and Coatney, Menkhaus, and Schmitz report negative relationships between feeder cattle price and weight. Dhuyvetter and Schroeder report a

positive, but declining relationship between price and weight. However they emphasized that interactions in their model made it difficult to interpret the marginal effects of each variable. Marsh assumed feeder cattle placement weights were important to the cattle feeding decision, but found only indirect supportive evidence. Other variables affecting feed prices have been Fed-cattle futures prices past profits (Kastens and Schroeder) and seasonality (Dhuyvetter and Schroeder; Anderson and Trapp), cattle cycles (Simpson and Alderman), recent feeding margins (Dhuyvetter and Schroeder), and sex (Dhuyvetter and Schroeder; Lambert et al).

Results characterizing the relationship between feed prices and feeder cattle weights also have been mixed. Some authors report positive relationships between corn prices and feeder cattle weights (Dhuyvetter and Schroeder; Anderson and Trapp). Heavier weight placements leave calves on feed for shorter periods, thus, consuming less high-priced corn (for example, Marsh). Buccola reports that an increase in corn price caused a decrease in feeder cattle price (an implied positive relationship between feeder cattle quantity and corn price).

A Cost Function

Treating feeder cattle of different weight categories as distinct inputs into fed-cattle production is a logical, theoretical construct for examining the derived demand for distinct weight categories of feeder cattle. A cost function allows one to derive a system of demand equations for estimation via Shepherd's Lemma (Dewiert; Young et al.). In the model specified here, feeder cattle of distinct weight categories are treated as distinct elements of an input vector, **x**, each with a distinct price per unit in a corresponding input

price vector, **w**. Other inputs, such as feeds, and their prices can be included as elements in the input and price vectors as well. Output, y, is represented as the total number of feeder cattle multiplied by the average slaughter weight; ignoring death loss.

While many functional forms are available for specifying a cost function the Generalized McFadden cost function is notable for its ease of use (Dewiert and Wales). It automatically satisfies most properties of cost functions including homogenity (see Varian), but does not satisfy conditions of symmetry and concavity in input prices. However, these conditions can be easily imposed[1]. The Generalized McFadden cost function specified for the cattle feeding application is:

$$(1) \quad C(w,Y) = \sum_i b_i w_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} (w_i w_j / w_k) + \sum_i \lambda_i w_i Y + \sum_i \sum_r \eta_{ir} w_i O_r + \sum_r O_r Y$$

where O_r = other variable(s) r, and i, j represents feeder cattle four weight classes and two feed categories which together ensure (i,j = 6).[2] The numeraire, w_k, is the price of one weight class of feeder cattle. In the feedlot model O_r are seasonal variables, S_r, explicitly defined below. By this notation and by applying Shephard's Lemma, the first derivative with respect to input prices yields conditional input demands which can be written as

$$(2) \quad \partial C(w,Y) \Big/ \partial w_i = x_i = b_i + \sum_j \beta_{ij}(w_j / w_k) + \lambda_i Y + \sum_r \eta_{ir} S_r .$$

The numeraire insures input demands are homogenous of degree zero in input prices.

By jointly estimating demands for different weight categories along with demand for feed, it is possible to obtain own- and cross-price effects on each weight category. This may reveal whether demands for each category of feeder cattle are complementary or substitute inputs. In this paper, complementarity is interpreted as support for an

alternate hypothesis of multiple classes of cattle feeding enterprises. Including feed demand allow us to examine category (feed), feed price (category price) relationships.

Empirical Model Estimation and Results

This section presents estimation of, and results from, a version of the Generalized McFadden cost function specified as an Error Correction Model (ECM) (Friesan; Friesan, Capalbo, and Denny). The ECM consists of two components, a levels (equilibrium) component and an unconstrained, differenced (disequilibrium) component. Joint estimation of both components of a nonlinear ECM model is the preferred estimation procedure. However, additional nonlinearities in specification of our model led to a failure to converge.[3]

Engle and Granger introduced a two-step estimation procedure for ECM's that has been widely used. A levels model is estimated and then, the lagged errors from the levels component (first step) are used as explanatory variables in estimating the disequilibrium component (second step) of the model. Parameter estimates on the lagged errors can be used to calculate the speed of adjustment to long run equilibrium.[4] In accounting for disequilibrium, the second step accounts for specification errors in the first step. Engle and Granger demonstrate the consistency of these two-step estimates.

The Engle-Granger two-step procedure is extended here by introducing a third step in which the adjustment parameter, v_i, is set and all remaining parameters of the ECM model are jointly estimated. This third step addresses two issues. First, it further reduces specification bias in the first step estimates. Second, it allows information relevant to long run disequlibrium that is discovered in step two to be incorporated in the model.

Data

All data are monthly, beginning with December 1995 and continuing through July 2003.

Feeder cattle data consist of the number of head in each of four weight categories placed

on feed: under 600 pounds, 600 to 699 pounds, 700 to 799 pounds, and over 800 pounds

(National Agricultural Statistics Service (USDA-NASS)). Price data for feeder cattle are

from Economic Research Service's *Red Meats Yearbook*, compiled from USDA's

Agricultural Marketing Service publications: Prices per hundredweight (cwt) for

Oklahoma City feeder cattle for Medium, Number 1 steers weighing 500 to 550 pounds

(for the under 600 pound weight class), steers weighing 600 to 650 pounds (600 to 699

pound class), heifers weighing 700 to 750 pounds (700 to 799 pound class), and steers

weighing 750 to 800 pounds (over 800 pound class) are used as proxies for prices for

each weight category. Prices for the 700 to 799 pound feeder cattle are proxied by using

feeder heifer prices because the steer price series was not included in the data source.

The use of these heifer prices is also of little concern because the weight classes include

both steers and heifers. Using this heifer price series as a proxy or instrument also may

reduce some of the collinearity among the price series. Feed prices are monthly from

ERS' "High Plains Cattle Feeding Simulator" (USDA-ERS, *Livestock, Dairy, and Poultry*

Outlook). ERS compiles these prices from AMS' *Grain and Feed Weekly Summary and*

Statistics.

The feed variables were reduced from 5 inputs to 2 by decomposing feed data into

two nutrient variables, protein and energy[5]. Breaking feed into nutrient components

allowed us to specify a parsimonious, five-equation model consisting of two feed demand

equations and three equations representing demand for feeder calves of each of three weight categories. The protein and energy content of two basic feeds, corn (or milo-which is similar to corn in feeding value) and cottonseed meal were used to derive prices for protein and energy.

Results From the Empirical Model

Our primary objective was to derive demand elasticities for the various weight categories and for feed. As such, the equilibrium component of the model is more relevant as it conforms to economic theory. As noted earlier our third step allows us to improve first-stage estimates, by using information obtained from estimating the disequilibrium component of the model, to re-estimate equilibrium relationships.

A general iterative procedure was used to estimate the ECM in three steps. First, the long run component of the model was estimated; imposing the required economic restrictions on model parameters. Second, the difference component of the model was estimated; using lagged error terms from the first step estimation as explanatory variables. Third, adjustment rates were set to their second stage estimates and the entire ECM model estimated (Appendix). This third step reduces the level of nonlinearity in the model, and made it possible for the joint model to converge.

Seasonality

NASS placement-weight data for states exhibits interesting seasonal patterns for each weight category. In Texas (figure 2), this seasonality is characterized by peak placements of heavier cattle during the spring (when many feeder cattle are removed from wheat

pasture), and peak placements of the lightest-weight cattle during the fall (after weaning).

Trigonometric functions were used to capture seasonal variations, which were tested for

both frequency and location (Anderson and Trapp; Arnade and Pick). The S_r from

equation (2) were specified as

$$(4) \qquad S_r = a_r \cos(2\pi t/n_r) + b_r \sin(2\pi t/n_r),$$

where r=1 for one peak per year, 2 for two peaks per year, t = time proxied by

observation number (integers beginning with 1), n_1=12 (months per cycle), and n_2=6

(months per cycle).

Most trigonometric parameters were significant for seasonal variations in all

feeder cattle equations (table 1) and indicate a consistency with other studies reporting

significant seasonal variation in feeder cattle demand (Anderson and Trapp; Coatney,

Menkhaus, and Schmitz; Dhuyvetter and Schroeder). Anderson and Trapp used both

annual and semiannual trigonometric functions similar to those used in this study to

capture seasonality. However, in contrast to Anderson and Trapp, our results support the

semiannual cycle for feeder cattle. Dhuyvetter and Schroeder also reported significant

interactions between weight and monthly dummy variables. Results in table 1 also

suggest semiannual seasonal, but not annual, patterns for both energy and protein.

Pairwise tests for seasonal location similar to those used by Arnade and Pick, but

between equations and without the time trend, showed significantly different seasonal

patterns between under 600-pound feeder cattle and 600 to 699-pound feeder cattle and

between under 600-pound feeder cattle and energy.

In addition to the statistical test results, patterns calculated, using trigonometric

function parameter estimates of intra-year cyclical behavior, are consistent with observed

data in figure 2. The calculated patterns (ECM model) have annual peaks in June for

600-to-699-pound and 700-to-799-pound feeder cattle placements and in November for

placements weighing under 600 pounds. This would be consistent with cattle coming off

wheat pasture and going into feedlots during the first part of the year. While not

conclusive, these different patterns, particularly for the under-600-pound weight

category, support the hypothesis of multiple classes of cattle feeders. In this case, the

evidence suggests one pattern of placing lighter (under 600-pound), just-weaned feeder

calves in the fall for longer term feeding, and a second pattern of placing heavier feeder

cattle in the spring for shorter feeding periods.

Feeder Cattle Weight and Feed Relationships

Published price-weight data indicate a general pattern of declining unit prices as feeder

cattle weight increases (USDA-AMS), although there are occasional inversions and

numerous offsetting factors (Lambert et al.). Results presented in tables 2 and 3 suggest

systematic patterns that were not evident in the mixed results reported in earlier studies.

Own price elasticities are negative and increase in absolute value as weight

increases (table 3). The relative inelastic finding on (absolute value) own-prices obtained

in all three specifications for the lightest weight class suggest a relatively inflexible

feeding enterprise. The increasing magnitudes (absolute values) of own-price elasticities

across all weight categories points to an inverse relationship between own price elasticity

and weight category. This may reflect a decreasing likelihood of retained ownership (as

feeder cattle get heavier and options for their uses decrease), recognizing that, ultimately,

almost all cattle are converted to beef. Own-price elasticities *may* increase (absolute

value) with weights because heaviest weight feeder cattle are in relatively shorter supply. They also have the fewest options available for their use, so large price changes would be necessary to change quantities demanded.

Symmetry and homogeneity conditions were used to obtain elasticities for the numeraire. The calculated own-price elasticity for the heaviest (over 800 pounds) class of feeder cattle is too large to be believable. Likely an artifact of the procedure used in its calculation, it is probably only useful as an indicator of the continuation of the general pattern observed in the other elasticities, which were directly derived from estimated parameters.

If there are multiple weight-based feeding regimes that characterize the cattle feeding industry, one could expect mixed results from using data in which detail about weight categories and feeding regimes was missing or obscured. Imagine two distributions of placement weights, one for light calves skewed to the right and one for heavy calves skewed to the left. The "average" across both distributions would fall in the skewed tail regions of both distributions and not reflect either mean.

Cross elasticities between weight groups also are presented in table 3. Generally, one would expect positive (negative) cross-price elasticities if cattle in each weight class were substitutes (complements). The positive results in table 3 provide evidence for substitution between the heaviest weight category and the next two lighter weight categories. However, the cross elasticities between the lightest weight category and the next heavier weight categories are negative. Thus, it appears that lightest weight cattle are not necessarily substitutes for heavier-weights of feeder cattle, again, consistent with feeding lighter cattle being a different enterprise from feeding heavier cattle.

The cattle-feeding literature implies that higher corn prices favor heavier weight placements that will be on feed for shorter periods and, thus, eat less high-priced corn (for example, Marsh; Jordan et al). Similar expectations exist for protein feeds—when protein feed prices are high, it is more efficient to feed heavier cattle whose protein requirements are slightly lower than lighter cattle, and heavier cattle are on feed less time. Results from other studies with respect to protein and energy are mixed and lack the systematic components presented here to explain differences (table 3). For example, some results (Anderson and Trapp; Dhuyvetter and Schroeder; Buccola) show positive relationships between energy and protein prices and feeder cattle weight. In the ECM model presented here, a systematic shift can be observed from negative to positive cross elasticities over feeder cattle weight class from most negative (lightest cattle) to most positive (heaviest cattle). One interpretation is that substitution doesn't matter so much for lighter weight feeder cattle placements, whereas for heavier weight feeder cattle placements on feed for shorter periods, substitution is more of an issue.

The highly inelastic own price elasticities for energy and protein also suggest that protein and energy are not substitutes in the same sense that different feedstuffs might be, but are necessary inputs for each weight category of feeder cattle. The near-zero cross elasticities between energy and protein further suggest fixed proportions between energy and protein, as one would expect in cattle feeding rations (see Weichenthal, Rush, and Van Pelt).

Conclusions

Feeder cattle costs constitute the largest cost share of cattle feeding costs. Feed costs are next, but well below feeder cattle costs. Other costs are relatively minor compared to these two. As such, energy or protein prices may not be the most important determinants of placement weights of feeder cattle. Systematic patterns between feed-input prices and feeder cattle in-weights may have not been captured by earlier studies, which have produced mixed results.

Our study looks at the demand for feeder cattle by weight category. Results in this paper provide some rationale for the mixed results observed across previous studies, with some general patterns emerging. We found negative cross-elasticites between lightest-weight feeder cattle and other weight categories which suggests cattle feeders placing lightest-weight feeder cattle constitute a distinct class of cattle feeders. Viewing the results presented here in the context of multiple classes of cattle feeders, we conclude that there is substitution between the heaviest weight category and the next two weight categories. We also conclude that the lightest-weight categories of feeder cattle are less likely to be viewed as substitutes with heavier weight classes and represent inputs into a separate class of cattle feeding enterprise.

While we have examined several aspects of the complex relationships between weight classes of feeder cattle in more detail, others aspects have not been examined. One such aspect is the pricing and feed cost-weight gain relationships between steers and heifers, which is left for future research. This extension would introduce additional multicollinearity in a model which already faces multicollinearity. A basic approach was used in this study to overcome the severe collinearity in the data series. Perhaps a more

sophisticated approach may be required for models which further decompose feedlot

demand. Other issues to be explored in determining feeder calf demand are retained

ownership, pasture expenses, price risk, interest rates, and other supply-related issues.

Several researchers (Jordan et al.; Mark, Schroeder, and Jones; Marsh), note that these

issues and other factors associated with pasturing cattle tend to equalize *overall* costs.

Future studies also could face problems with obtaining sufficiently detailed and

disaggregated data for all the desired subcategories and well as data required to address

these other issues-which may influence in-weights.

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Table 1. Estimated Parameters for Third Step of Error Correction Model[a,b]

Cholesky Matrix Parameters:

	C_{i1}	C_{i2}	C_{i3}	C_{i4}	C_{i5}
C_{1j}	-14.086***				
C_{2j}	-2.2858	4.9108			
C_{3j}	1.4037	-12.879	-12.888		
C_{4j}	-1.9914	-2.1841	1.7426	0.0000000***	
C_{5j}	-25.57*	10.635	-21.312	0.000000629***	-.000000005***

Intercept (Int), Output (Y), and Seasonal Parameter Estimates:

Int	89.07**	24.308	88.675	118.18***	664.53***
Y^c	0.0001947***	0.0002115***	0.0002714***	-0.000013	0.0006719
Sin1[d]	-0.155	-0.5791***	0.04905	-0.39346	3.4514
Cos1	200260***	154490***	527800***	202430***	313350***
Sin2	-34.77***	0.82341	32.85***	19.696	208.03
Cos2	-220200***	-169880***	-580360***	-222590***	-344340***
v_i^e	-0.61815***	-0.66918***	-0.74583***	-0.51094***	-0.46481***

[a]Subscripts: 1= feeder cattle (fc) under 600, 2=fc 600 to 699, 3=700 to 799, 4=Protein, 5=Energy
[b]statistical significance denoted by asterisks: *=significance at the .05 level, **=.01, ***=.005
[c]Y=Output= total number of feeder cattle multiplied by the average slaughter weight
[d]Cosx=Cosine(x), Sinx=Sine(x); x=1 refers to a frequency of once a year, x=2, twice a year.
[e]Adjustment parameter

Table 2. Price Coefficients Calculated from Cholesky Matrices[a,b]

| Equation	X_1	X_2	X_3	X_4	X_5
P_1	-198.42	-32.198	19.77	-28.05	-360.18
P_2	-32.20	-29.341	66.455	6.174	-110.674
P_3	19.77	66.455	-333.9396	-2.875067	-101.8083
P_4	-28.05	6.174	-2.875067	-11.77262	9.446097
P_5	-360.18	-110.674	-101.8083	9.446097	-1221.129

[a]Price parameters derived from estimated parameters of the Cholesky Matrix
[b]Subscripts refer to 1=fc (feeder cattle) under 600, 2=fc 600 to 699, 3=700 to 799, 4=Protein, 5=Energy

Table 3. Feeder cattle and feed Price Elasticities
-- December 1995 Through June 2003--

| | Numerator | | | | | |
Denominator	Feeder cattle under 600 pounds	Feeder cattle from 600 to 699 pounds	Feeder cattle from 700 to 799 pounds	Feeder cattle over 800 pounds	Protein	Energy
Feeder cattle under 600 pounds	-1.86	-0.256	0.17127	5.7126	-0.068	-0.11605
Feeder cattle from 600 to 699 pounds	-0.28	-0.217	0.53928	0.11171	0.014053	-0.03338
Feeder cattle from 700 to 799 pounds	0.163	0.468	-2.582	5.14	-0.00614	-0.02914
Feeder cattle over 800 pounds	2.156	0.02755	1.9133	-26.81	0.065278	0.192
Protein	-0.0494	0.009203	-0.00472	0.68428	-0.00546	0.000576
Energy	-0.13016	-0.03206	-0.03233	14.535	0.000819	-0.0143
Output	0.95505	0.88371	1.2467		-0.1583	0.11413
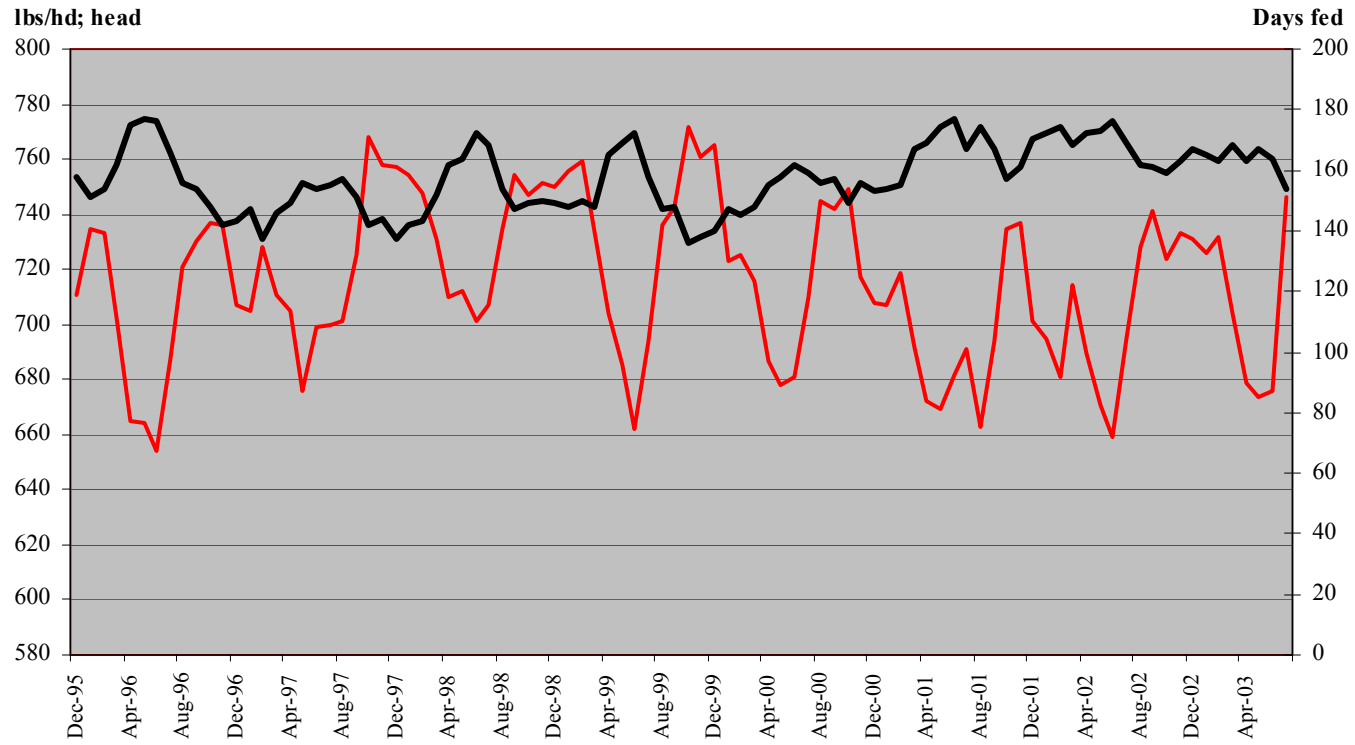
Figure 1. Steer Placement Weights and Days Fed

Source: Hoelscher
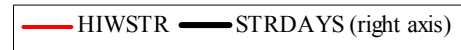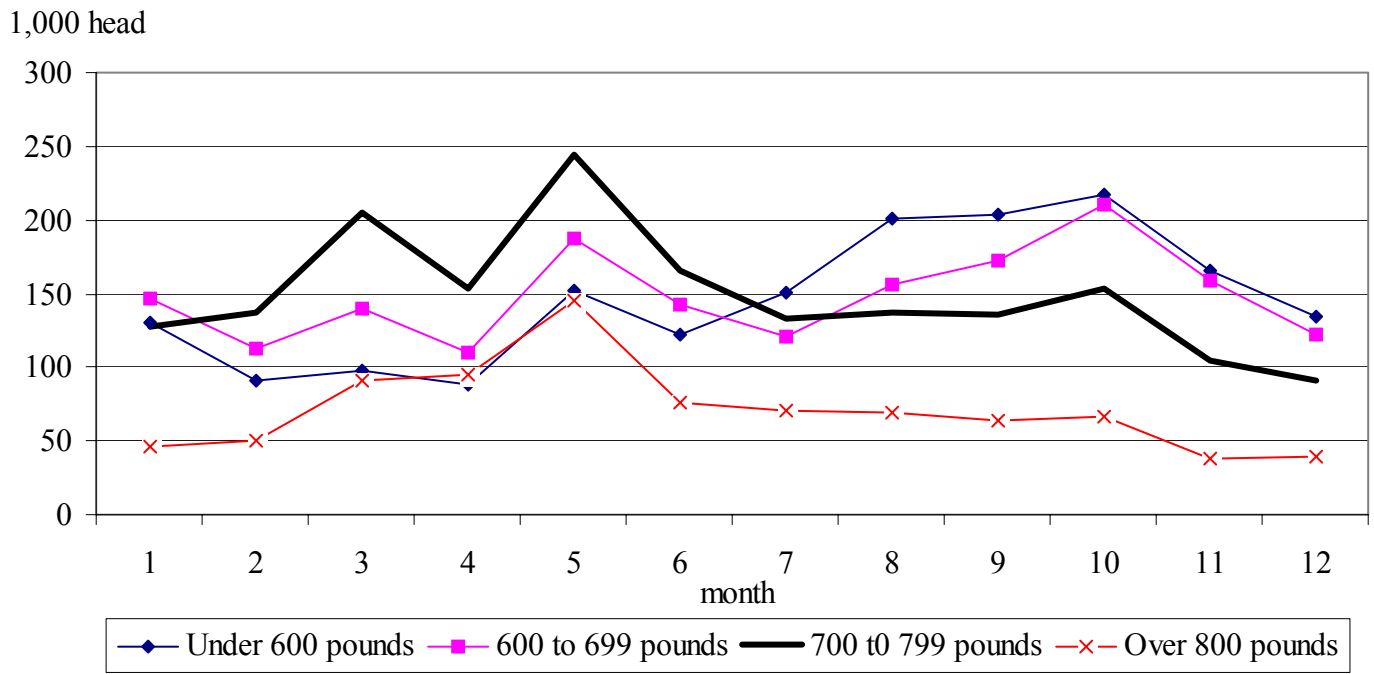
Figure 2. Texas Feeder Cattle Placements, By Weight Category, 1999-2003

Endnotes

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[1] An adequately representative cost function must be concave in the price of the inputs. That is, the matrix of second derivatives (represented by the β_{ij} parameters) of the Cost function with respect to input prices must be negative definite. Diewert and Wales collect the β_{ij} parameters into a matrix and show that, by representing this matrix as the product of a lower triangular matrix and its transpose, it is possible to impose concavity of the cost function at every data point (See Appendix). This procedure also insures that symmetry conditions hold and that input demands are downward sloping.

[2] We have two feed categories, protein and energy derived from five feeds.

[3] This was a particular problem since we also imposed concavity restrictions using a procedure suggested by Diewert and Wales.

[4] The two-step estimation strategy is not ideal and constrains the ability to test for various nested dynamic structures.

[5] Several approaches were explored for a feed variable. However, the imposition of concavity restrictions on a weighted index variable for the original 5 feedstuffs yielded a highly nonlinear specification, the results from which were not well-behaved. Weights were not bounded between zero and one and some were negative. A grid search was also used to explore fixed weights for corn and cottonseed meal, representing energy and protein. Results from this effort revealed an optimal weighting scheme of 0.2 for corn

and 0.8 for cottonseed meal, approximately the reverse of a typical feeding ration

weighting of approximately 16 percent protein. Also, the likelihood values changed by

less than 1/500 across all the parametrically varied weights, indicating that preset feed

weights would have little overall effect on the model.