An Inverse-Demand Model of Weekly Boxed Beef Prices

by

Stephen R. Koontz, James N. Trapp,

and Steven E. Meyer

Suggested citation format:

Koontz, S. R., J. N. Trapp, and S. E. Meyer. 1994. "An Inverse-Demand Model of Weekly Boxed Beef Prices." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

AN INVERSE-DEMAND MODEL OF WEEKLY BOXED BEEF PRICES

Stephen R. Koontz, James N. Trapp, and Steven E. Meyer*

Short-term meat and livestock price dynamics have been extensively investigated by agricultural economists. Research in this area has been largely concerned with identifying price discovery processes and has examined interactions between prices at different levels of the marketing channel, between spatial markets, and between cash and futures markets (Bessler and Brandt, Boyd and Brorsen; Purcell and Hudson; Schroeder and Goodwin; Schroeder and Hayenga). Relatively little research has examined the short-run structural relationships underlying meat and livestock price movements. Some of the work in this latter area includes Hayenga and Hacklander, Marsh, and Marsh and Brester.

This research is an expansion on part of the research by Marsh and Brester. Their work examined the structural relationship between boxed beef price, beef and veal slaughter, pork and lamb slaughter, chicken and turkey slaughter, and other factors, in an inverse-demand model. Their objectives were to summarize the dynamic behavior of weekly boxed beef prices in response to changing beef slaughter and other structural economic variables. Our research has similar objectives and makes improvements on their work.

Knowledge of the dynamic structural response by boxed beef prices to changing fed cattle slaughter volumes is important for a number of agribusiness decision makers. This information is useful for making short-term forecasts of boxed beef prices which can be incorporated into decision making by meatpackers and feedlot managers. Feedlot operators can use the information to plan fed cattle marketings and meatpackers can use the information to plan cattle purchases and forecast gross margins.

In addition to providing information to agribusiness decision makers, this research is motivated by an experimental economics project. An experimental economics simulator of the fed cattle market is being developed by the authors (see Koontz et al.). A purpose for developing the simulator is to study the effects of forward contracting between feedlots and meatpackers on the cash fed cattle market. The simulator also allows study of the effects of market concentration on fed cattle price levels and dynamics. Effective experimentation requires the market simulator to capture the essential structural components of real-world fed cattle, feeder cattle, and boxed beef markets. Simulator participants comprise the fed cattle market -- they role play was feedlot marketing managers and meatpacker order buyers. Feeder cattle purchases by the feedlots and boxed beef sales by the meatpackers, respond to actions by the participants, but are exogenous to the simulator. Meatpacking firms in the simulator sell cattle purchases as processed meat to a dynamic boxed beef demand function which determines boxed beef price.

Initially, the dynamic price flexibilities estimated by Marsh and Brester were used in the experimental market. The experimental market operates on weekly time intervals. Thus, weekly price flexibilities were needed. However, for a given change in the weekly quantity of beef slaughtered, Marsh and Brester's results suggested the boxed beef market continues to adjust for over 17 weeks and that over 8 weeks are need for half of the adjustment to occur. This lengthy adjustment process caused problems in trials of the market simulator. A portion of the participants did not realize there was a demand function for boxed beef. Those that did recognize the demand function stated that the relationship was not important for decision making. Further, while psychological, technical, and institutional constraints

* Assistant professor and Regent's Professor in the Department of Agricultural Economics at Oklahoma State University, and market analyst with the American Sheep Industry Association.

will delay complete price adjustments, an intuitive understanding of the real-world boxed beef market suggests price adjustments occur and are completed more rapidly.

This research improves on past work in three ways. First, following Eales and Unnevehr, our inverse-demand model specifies weekly boxed beef price as a function of fed and nonfed beef slaughter. Pork and poultry slaughter, and other economic factors, are also included in our model. Fed beef typically enters the fresh beef marketing channel while nonfed beef enters the processed beef marketing channel. The perishability of fresh beef suggests this channel is shorter and price adjustments within the channel are rapid. Processed beef is often frozen and place in cold storage. This marketing channel is likely to be longer. Previous research has treated beef as a homogeneous product and may overestimate the length of the price adjustment process specifically for fresh beef.

Second, we use a modified-Hausman test to examine for simultaneity between weekly boxed beef prices and fed beef slaughter. Simultaneity between slaughter and prices can lead to small negative or possibly positive relationships between price and quantity in the contemporaneous time period. In a distributed lag model with polynomial restrictions on the coefficients, the resulting bias would be toward finding initial adjustments which are too small and a total adjustment which is too long.

Third, the dynamic adjustment processes are modelled through distributed lags on each slaughter series. The order and length of each adjustment process is determined through a routine developed by Pagano and Hartley. The procedure is an improvement on the rational distributed lag method.

Model Specification and Data

Demand for boxed beef is derived from retail demand for fresh beef. Demand for fresh beef is influenced by the price of fresh beef, prices of substitute meats, consumer income, and seasonal and permanent changes in preferences. Derived demand for boxed beef is influenced by the price of boxed beef, retail beef price, other input costs, and other output prices. The conceptual demand equations are

$$QDRetail = f_1(PRetail,\ PSubst,\ Income,\ Population,\ TP,\ \mu_1) \tag{1}$$

$$QDBoxBeef = f_2(PBoxBeef,\ PRetail,\ Wage,\ Byproduct,\ \mu_2) \tag{2}$$

where QDRetail is the quantity of fresh beef demanded at retail, PRetail is the retail fresh beef price, PSubst denotes substitute meat prices, Income is consumer income, Population is U.S. population, TP denotes changes in consumer tastes and preferences, QDBoxBeef is the quantity of boxed beef demanded, PBoxBeef is the boxed beef price, Wage denotes labor costs which are the largest variable input cost, Byproduct denotes the value of fed cattle byproducts, and μ_1 and μ_2 are random errors.

The perishability of boxed and fresh beef suggests a price dependent specification. Equations (1) and (2) are inverted and the inverse retail demand equation is substituted into the inverse boxed beef demand equation resulting in the following reduced-form inverse-demand equation for boxed beef price

$$PBoxBeef = g(QFedB,\ QNonfedB,\ QPork,\ QPoultry,\ Income,\ Trend,\ Season,\ \delta) \tag{3}$$

where PBoxBeef is the weekly deflated ($1982) boxed beef cutout value for Choice 2-3, 550-700 pound carcasses. QFedB is per capita weekly federally inspected fed steer and heifer slaughter multiplied by average steer and heifer dressed weights. QNonfedB is per capita weekly federally inspected cow and bull slaughter multiplied by average cow and bull dressed weights. QPork is per capita weekly barrow and gilt slaughter multiplied by the average barrow and gilt weight. QPoultry is per capita weekly pounds of chicken and turkeys slaughtered. Income is the weekly deflated ($1982) per capita income. A trend variable is used to capture a potential structural drift in beef price due to changing consumer preferences or processing costs. Seasonal variables are used to capture seasonal and holiday variations in weekly demand. The term δ denotes random error.

The boxed beef market is examined with weekly data from January 1980 through March 1990. The total number of steers, heifers, cows, and bulls slaughtered each week, the corresponding average dress weights, the total number of barrows and gilts slaughtered each week, the average dress weight, the total number of young chickens and turkeys slaughtered weekly, and the corresponding dress weights were reported by federally inspected slaughtering facilities. The information was released in the *Livestock, Meat, and Wool Market News* and the *Poultry Market News* publications and were complied by the Western Livestock Marketing Information Project (WLMIP). Weekly average boxed beef cutout values were also released in the *Livestock, Meat, and Wool Market News* publication and were provided by the WLMIP. Monthly per capita disposable income and the consumer price index (CPI) were gathered from U.S. Department of Commerce sources and provided through the WLMIP. Monthly population data was collected from the U.S. Census Bureau *Annual Summary*. The monthly income and population figures were divided by the number of weeks in each month to produce a weekly figure and then linearly interpolated to form a weekly series. The monthly CPI was assumed to represent a mid-month figure, and a weekly series was linearly interpolated from each point.

Real boxed beef price, real income, and per capita quantities are used in the inverse-demand equation. The delayed adjustment of beef price to changes in quantities of meat in the marketing channel is captured by polynomial distributed lags. The model is

$$PBoxBeef_t = \beta_0 + \sum_{j=1}^{p_1} \beta_{1j} QFedB_{t-j} + \sum_{j=1}^{p_2} \beta_{2j} QNonfedB_{t-j} + \sum_{j=1}^{p_3} \beta_{3j} QPork_{3j} + \sum_{j=1}^{p_4} \beta_{4j} QPoultry_{t-j} + \sum_{j=1}^{p_5} \beta_{j5} Income_{t-j} + \beta_6 Trend_t + \sum_{j=1}^{11} \beta_{7j} Month_t + \sum_{j=1}^{4} \beta_{8j} Holiday_t + \delta_t \qquad (4)$$

where

$$\beta_{ij} = \alpha_{i0} + \alpha_{i1} j + \alpha_{i2} j^2 + \alpha_{i3} j^3 + \cdots + \alpha_{im} j^m \qquad (5)$$

for i = 1, ..., 5. Contemporaneous values of each independent variable are included in the specification and each independent variable was possibly lagged different lengths. The polynomial associated with each independent variable has a different order and the potential for endpoint restrictions. Per capita nonagricultural nonsupervisory private sector labor earnings and real beef carcass byproduct values were included in the initial model. However, labor earnings and disposable income were correlated above 0.98, so labor earnings were removed to reduce collinearity problems. Byproduct values were not included in the final model because of lack of significance.

Polynomial distributed lags are specified for each independent slaughter series and the income series. An autoregressive error term of the following form

$$\delta_t = \sum_{i=1}^{p} \delta_{t-i} + \upsilon_t \qquad (6)$$

is also included. The lag length, order of the polynomial, and order of the autoregressive error were selected using a process suggested by Pagano and Hartley. The process involves selecting maximum possible lag lengths and polynomial orders, performing orthonormal transformations on the data matrices in models of these possible lag lengths and orders, and selecting the model with the smallest Mallow's C_p statistic. Mallow's C_p statistic is the sum of squared errors with a penalty for large numbers of parameters relative to observations. The orthonormal transformation improves numerical methods by removing collinear data. Autoregressive errors are incorporated through generalized differencing.

Estimation of equation (4) results in a small positive coefficient on the contemporaneous fed beef slaughter variable. Marsh and Brester find the same result. This suggests simultaneity between boxed beef prices and fed cattle slaughter. Thus, a modified-Hausman test was used to test the simultaneity hypothesis (Godfrey). Equation (4) can be rewritten as follows

$$y_{1t} = X_t\beta + y_{2t}\alpha + \delta_t \tag{7}$$

where y_1 is the dependent variable, X_t is a matrix of known independent variables, y_2 is an independent variable which is potentially endogenous, ß is a vector of coefficients, α is a coefficient, and δ is the error term. Simultaneity is tested by examining the significance of α in the following artificial regression

$$y_{1t} = X_t\beta + (y_{2t} - \hat{y}_{2t})\alpha + \delta_t \tag{8}$$

where $\hat{y}_2$ is a two-stage least squares projection of y_2. If the estimate of α is significant, simultaneity is indicated. Hausman tests are based on the idea that the results from an instrumental variable estimator should not be very different from a more efficient estimator if the variable in question is not endogenous. The modified test is based on the same idea, only the measurement of endogeneity is different. Intuitively, if the difference between y_2 and its projection explains movements in y_1, then y_2 is correlated with the residual and the model requires an instrumental variable estimator.

If simultaneity is found between boxed beef price and fed beef slaughter, this creates the need for a supply model to explain fed beef marketings. Excluded exogenous variables are needed for instruments to calculate the projection of contemporaneous fed beef slaughter. The supply equation is specified as follows. The majority of weekly marketings are determined by the number of market-ready cattle in feedlots, which is hypothesized to be primarily determined by past placements of cattle on feed. However, feedlots have the ability to adjust marketings on the margin. Lagged fed beef slaughter is included to capture the inertia in fed cattle marketings. Lagged fed beef slaughter captures the naive inventory-like adjustments in fed cattle marketings. A premium/discount variable between the current fed cattle price and the nearby live cattle futures contract price is introduced to capture producer expectations about short-term price changes. The premium/discount variable captures adjustments to fed cattle inventories due to forward-looking behavior of cattle feeders. Seasonal and holiday dummy variables and a trend variable are also included. The fed cattle slaughter equation is

$$\begin{aligned} QFedB_t = {} & \gamma_0 + \gamma_1 QFedB_{t-1} + \gamma_2 Placements_t + \gamma_3 Premium/Disc_t \\ & + \sum_{j=1}^{11} \gamma_{4j} Month_t + \sum_{j=1}^{4} \gamma_5 Holiday_t + \varepsilon_t \end{aligned} \tag{9}$$

where $Placements_t$ is the sum of placements 20 and 21 weeks prior, and Premium/Disc is the premium/discount variable. An autoregressive error term was incorporated. Monthly placement data from the seven state *Cattle on Feed* report were divided by the number of weeks in each month and linearly interpolated to form a weekly series. The cash price series used is the weekly boxed beef price converted to a live animal price (divided by 63%). The futures price series is a weekly average of closing prices from the nearby contract; the series rolls out of a given contract when that contract enters the delivery month.

Lagged placements explain the physical feeding process -- the closed system of the cattle feeding process. The trend and the dummy variables capture weather and other consistent patterns in feeding decisions. Lagged slaughter captures the physical inventory-like behavior of fed cattle marketings. The larger last week's marketings were, the larger this week's marketings will be -- outside of changes in slaughter due to change in placements and seasonal patterns. The premium or discount between cash and the nearby live cattle futures contract price captures forward-looking behavior by cattle feeders -- the variations in inventory due to expected price changes. This is basically the price variable in a short-run fed cattle supply function. The price level is not important, rather expected price changes are important.

Empirical Results

Results from the test for simultaneity suggest that fed beef slaughter is an endogenous variable in the inverse-demand function. The t-statistic is 8.4005, which is significantly different from zero at the 0.01% level. Thus, two stage least squares is used to estimate the demand model.

The inverse-demand model results are presented in table 1. The model has a first-order autoregressive error and an R-square of 97.9%. The Pagano and Hartley procedure for selecting the lag lengths of the independent variables and polynomial restrictions on the distributed lag coefficients suggests the following. Fed beef slaughter is lagged ten weeks and the polynomial is fourth order. Nonfed beef slaughter is lagged 12 weeks and the polynomial is also fourth order. Per capita pork and poultry slaughter and per capita disposable income have no significant contemporaneous or lagged effects on boxed beef prices. The trend variable is negative and significant suggesting that real boxed beef prices are declining over the sample period. This result may be due to changes in consumer tastes and preferences, or possibly the increasing trend in poultry production. Boxed beef prices exhibit a seasonal pattern, with higher prices during late summer and early fall and lower price during the winter.

Flexibilities and cumulative flexibilities for fed and nonfed beef are presented in figures 1 and 2. A one percent increase in per capita fed beef slaughter will result in a 0.094% decrease in boxed beef price the week of the change. Boxed beef price will be reduced by a total of 0.692% after ten weeks and half of the adjustment occurs within four weeks. A one percent increase in per capita nonfed beef slaughter does not have an immediate impact on boxed beef price. However, the boxed beef price will be reduced by 0.373% after twelve weeks and half of the adjustment occurs within seven weeks. Results reveal the institutional and product differences. Boxed beef adjusts immediately and rapidly to changes in fresh beef supplies. While boxed beef price does adjust to changes in nonfed beef supplies, these cattle are likely destine for processed meat markets and cold storage. Therefore, the boxed beef price reaction to changes in nonfed beef supplies is slower.

Figure 3 presents the flexibilities from the inverse-demand model with simultaneity incorporated between price and quantity and from a model where quantity is assumed exogenous. The results from the model with exogenous quantity are similar to those of previous research and reveal the problems with ignoring simultaneity. The dynamic structure suggests the boxed beef price is very slow to react to changes in slaughter quantities and that the reaction continues over a longer time period. The Pagano and Hartley procedure suggests the lag length is 16 weeks and that the polynomial is third order. The total flexibilities are similar, with the flexibility for the model with exogenous quantity being smaller.

However, the model suggests seven weeks are needed before the boxed beef price has completed half of the adjustment to a change in fed beef quantity.

The fed beef slaughter model results are presented in table 2. The model has a first-order autoregressive error and an R-square of 54.4%. The variations in fed beef slaughter which can be explained are largely explained by placement levels, seasonal factors, and past slaughter levels. The model's trend variable and autoregressive error term are also important. The coefficient on the variable which captures the premium and discount between the current cash price and the nearby live cattle futures contract price has the anticipated sign but is significant at the 9% level. Fed beef slaughter exhibits inventory-like behavior based on the results of the lagged dependent variable. When the current week's slaughter is large, the next week's slaughter will also likely be large -- even when accounting for slaughter-level variations due to placements and seasonal feeding patterns. Further, their are mild adjustments to the marketing of fed cattle inventory which is responding to future price expectations. When future prices are expected to increase, current marketings decline.

Summary and Conclusions

The results of our work suggest boxed beef market dynamics are rather different than what has been previously reported. There are three important differences in our findings. First, weekly boxed beef prices and fed beef slaughter are simultaneous. While fed beef is often modelled as a nonstorable commodity with predetermined supply, it appears that in the short run there is inventory-like behavior when cattle have reached minimum weight and grade. We also find that specification of an inverse-demand model for boxed beef prices that ignores simultaneity results is no significant contemporaneous impact of changes in slaughter and a long lagged adjustment process to changes in slaughter. This is consistent with previous research. Incorporating simultaneity into the inverse-demand model was found to be a crucial step for modelling the dynamic structure of boxed beef price adjustment.

Second, the largest portion of the boxed beef price adjustment process occurs within four weeks of slaughter and the adjustment is complete in ten weeks. The adjustment by boxed beef price to nonfed beef slaughter is slower and is consistent with nonfed beef representing frozen or processed beef which is a substitute for boxed or fresh beef. The large contemporaneous and rapid own-price adjustment result is new. Results of previous research may be biased by the aggregation of fed and nonfed beef or exclusion of nonfed beef as well as simultaneity.

Third, the results associated with other substitute meats (other than nonfed beef) suggest that in a weekly boxed beef inverse-demand model, slaughter levels of substitute meats have no affect. This result is new and may be due to including simultaneity into the model and/or the increased flexibility in the type of distributed lag model used.

These results should be useful to agricultural and extension economists and cattle and beef industry professionals who are interested in understanding and forecasting boxed beef price variations. Further, for agricultural economists interested in modelling livestock prices the results suggest simultaneity needs to be considered even in short-run demand models. Last, this research documents the structure of boxed beef demand incorporated into a fed cattle market simulator which is being used to conduct economic experiments.

Table 1. Parameter Estimates, Standard Errors, and Model Statistics for the Inverse-Demand Model of Boxed Beef Prices.

Variables	Parameter Estimate	Standard Error	Variables	Parameter Estimate	Standard Error
Intercept	203.130*	32.642	QPork	-1.430	1.226
QFedB(t)	-6.310*	1.872	QPoultry	0.333	0.616
QFedB(t-1)	-5.728*	0.863	Income	0.075	0.133
QFedB(t-2)	-5.069*	0.998	Trend	-0.072*	0.015
QFedB(t-3)	-4.541*	0.984	February	-0.254	0.558
QFedB(t-4)	-4.253*	0.929	March	0.019	0.760
QFedB(t-5)	-4.212*	0.954	April	-0.123	0.925
QFedB(t-6)	-4.324*	0.987	May	1.131	1.012
QFedB(t-7)	-4.392*	0.989	June	0.866	1.122
QFedB(t-8)	-4.119*	0.977	July	0.731	1.142
QFedB(t-9)	-3.106	0.880	August	1.043	1.163
QFedB(t-10)	-0.851	0.829	September	2.049*	1.141
QNonfedB(t)	1.181	4.390	October	2.527*	1.101
QNonfedB(t-1)	-1.428	3.368	November	1.828*	1.077
QNonfedB(t-2)	-4.249	3.589	December	1.891*	0.875
QNonfedB(t-3)	-7.062*	3.363	Xmas	-0.474	0.625
QNonfedB(t-4)	-9.664*	2.994	Thanksgiving	0.831*	0.403
QNonfedB(t-5)	-11.869*	2.908	July 4th	-0.214	0.467
QNonfedB(t-6)	-13.503*	3.065	Memorial Day	0.525	0.546
QNonfedB(t-7)	-14.409*	3.155	Labor Day	-0.512	0.516
QNonfedB(t-8)	-14.444*	3.050	$\rho(t-1)$	0.937*	0.015
QNonfedB(t-9)	-13.482*	2.894			
QNonfedB(t-10)	-11.411*	2.923	R^2	0.979	
QNonfedB(t-11)	-8.134*	3.044	Adjusted R^2	0.978	
QNonfedB(t-12)	-3.569	2.810			
QNonfedB(t-13)	2.350	2.538			

* Significant at the 5 percent level.

Table 2. Parameter Estimates, Standard Errors, and Model Statistics for the Fed Beef Supply Model.

Variables	Parameter Estimate	Standard Error	Variables	Parameter Estimate	Standard Error
Intercept	0.6227*	0.0515	October	-0.0068	0.0145
QFedB(t-1)	0.5672*	0.0348	November	-0.0913*	0.0160
Premium/Disc	-0.0002**	0.0001	December	-0.0289*	0.0140
Placements	0.0001*	0.0000	Xmas	-0.3351	0.0263
Trend	0.0000	0.0000	Thanksgiving	0.0330	0.0282
February	-0.0782*	0.0141	July 4th	-0.1732*	0.0263
March	-0.0740*	0.0128	Memorial Day	-0.1127*	0.0259
April	-0.0441*	0.0132	Labor Day	-0.0651*	0.0257
May	0.0121	0.0152	ρ(t-1)	-0.3114*	0.0481
June	-0.0088	0.0144			
July	0.0089	0.0142	R^2	0.544	
August	0.0079	0.0142	Adjusted R^2	0.527	
September	0.0080	0.0145			

* Significant at the 5 percent level.
** Significant at the 10 percent level.

Figure 1. Fed Beef and Nonfed Beef Flexibilities.

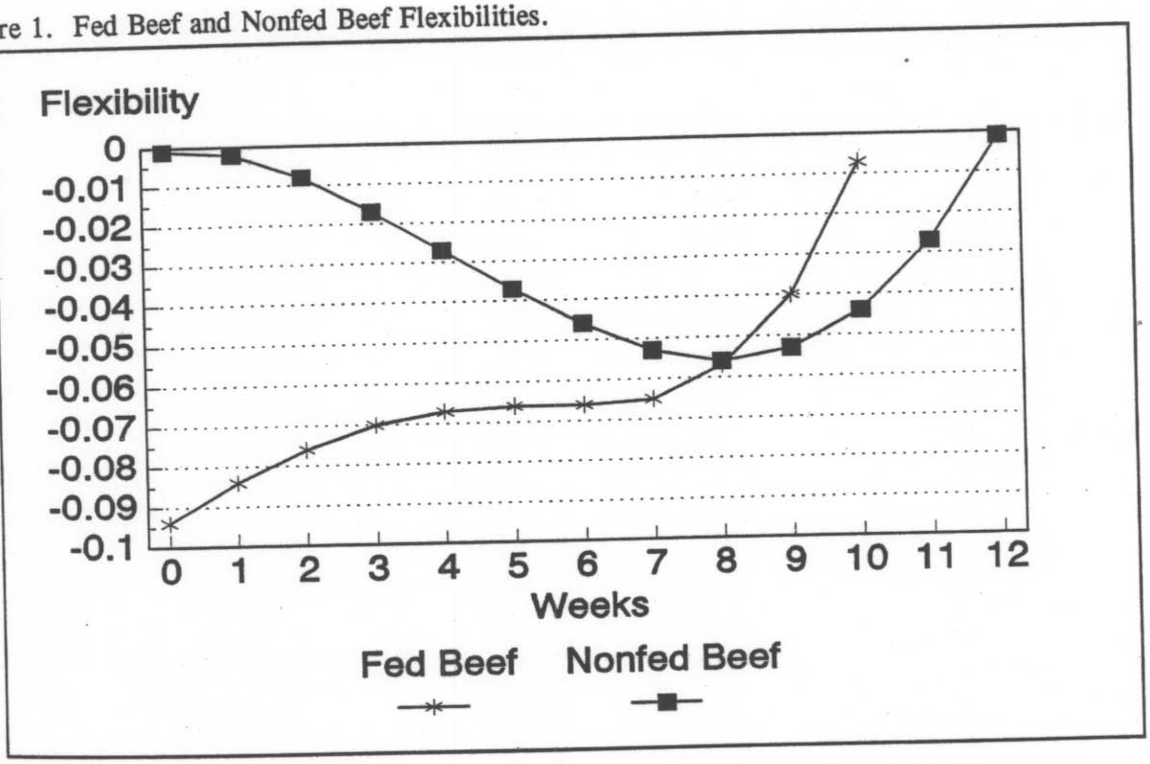


Figure 2. Fed Beef and Nonfed Beef Cumulative Flexibilities.

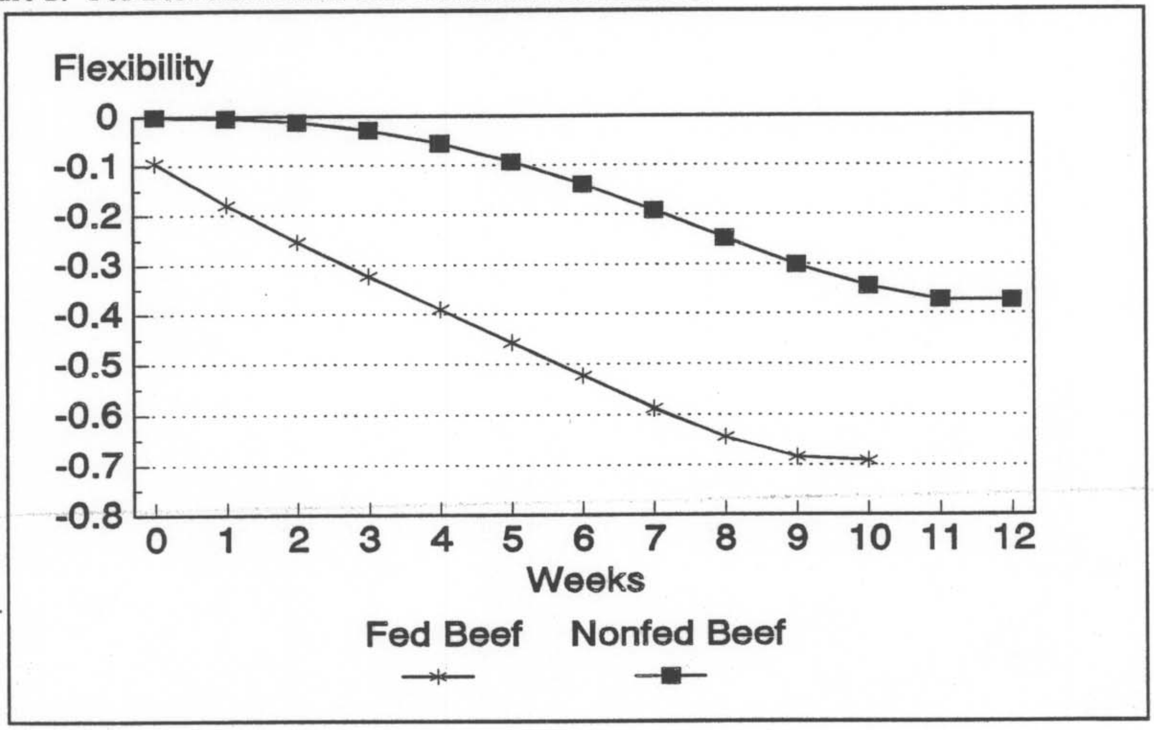
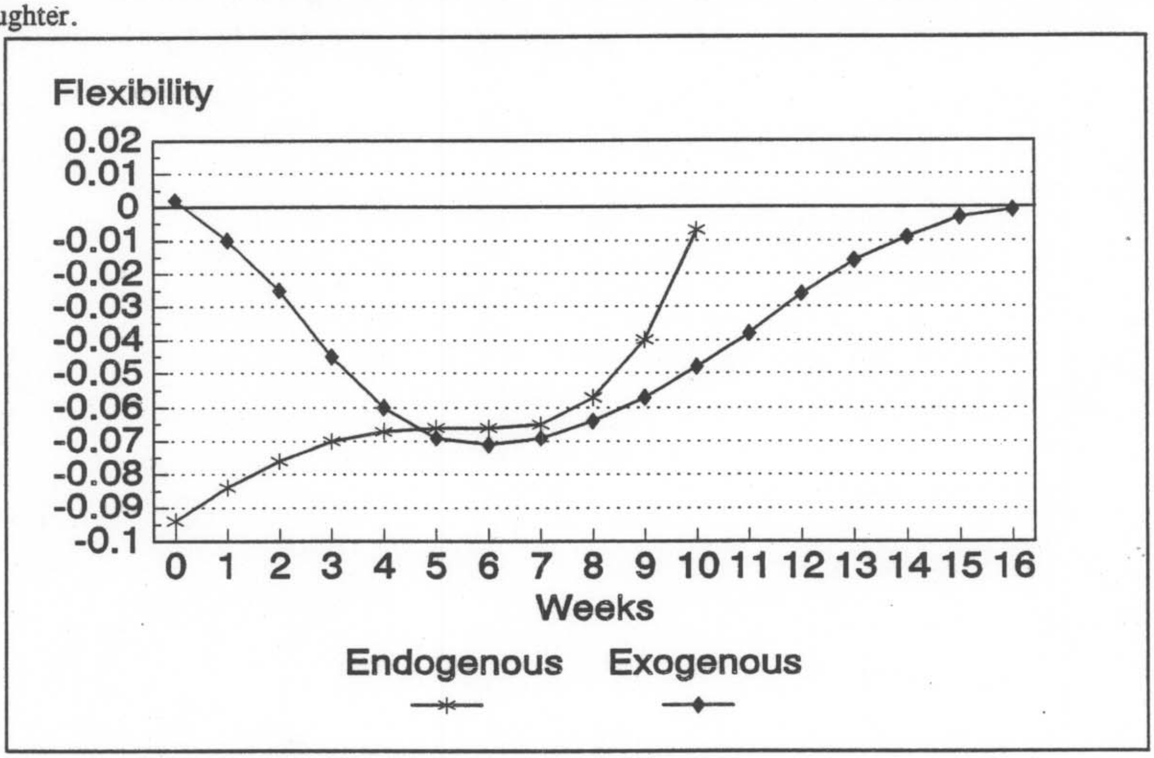


Figure 3. Fed Beef Flexibilities from the Models with Endogenous and Exogenous Contemporaneous Slaughter.



REFERENCES

Bessler, D.A., and J.A. Brandt. "Causality Testing in Livestock Markets." *American Journal of Agricultural Economics* 64(February 1982): 140-144.

Boyd, M.S., and B.W. Brorsen. "Dynamic Relationships of Weekly Prices in the United States Beef and Pork Marketing Channels." *Canadian Journal of Agricultural Economics* 57(November 1985): 331-342.

Eales, J.S., and L.J. Unnevehr. "Demand for Beef and Chicken Products: Separability and Structural Change." *American Journal of Agricultural Economics* 70(August 1988): 521-532.

Godfrey, L.G. *Misspecification Tests in Econometrics: The Lagrange Multiplier and Other Approaches*. Cambridge: Cambridge University Press, 1988.

Hayenga, M.L., and D. Hacklander. "Monthly Supply-Demand Relationships for Fed Cattle and Hogs." *American Journal of Agricultural Economics* 52(February 1970): 535-544.

Koontz, S.R., D.S. Peel, J.N. Trapp, and C.E. Ward. "Experiential Learning Using A Fed Cattle Market Simulator: The 'Packer-Feeder' Game." Oklahoma Agricultural Experiment Station Research Report P-929 Oklahoma State University December 1992.

March, J.M. "A Rational Distributed Lag Model of Quarterly Live Cattle Prices." *American Journal of Agricultural Economics* 65(August 1983): 539-547.

March, J.M., and G.W. Brester. "Intertemporal Price Adjustments in the Beef Market: A Reduced Form Analysis of Weekly Data." *Western Journal of Agricultural Economics* 14(December 1989): 235-245.

Pagano, M., and M.J. Hartley. "On Fitting Distributed Lag Models Subject to Polynomial Restrictions." *Journal of Econometrics* 16(June 1981): 171-198.

Purcell, W.D., and M.A. Hudson. "The Economic Roles and Implications of Trade in Livestock Futures." *Futures Markets: Regulatory Issues*, A. Peck ed. Washington D.C.: American Enterprise Institute for Public Policy Research 1985.

Schroeder, T.C., and M.L. Hayenga. "Short-Term Vertical Market Price Interrelationships for Beef and Pork." *North Central Journal of Agricultural Economics* 9(July 1987): 171-180.

Schroeder, T.C., and B.K. Goodwin. "Regional Fed Cattle Price Dynamics." *Western Journal of Agricultural Economics* 15(July 1990):111-122.

Azzam, A., and J.F. Yanagida. "A Cautionary Note on Polynomial Distributed Lag Formulations of Supply Response." *Western Journal of Agricultural Economics* 12(July 1987): 60-64.

Eales, J.S., and L.J. Unnevehr. "Simultaneity and Structural Change in U.S. Meat Demand." *American Journal of Agricultural Economics* 75(May 1993): 259-268.