AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry

Gary W. Brester and John M. Marsh

An annual dynamic model of the primary and derived levels of the U.S. beef industry was estimated by rational distributed lags. Geometric rational lags at the retail level were instrumental in establishing prices in the dressed meat trade and the slaughter and feeder levels. Polynomial rational lags characterized primary inventory supply, which, along with cattle and corn prices, determined the production of fed and nonfed beef. The results suggest that the short- and long-term market behavior in the beef industry is better understood when higher and lower order market interactions are taken into account.

This paper presents a statistical system of price, demand, and supply equations describing the U.S. beef industry within a rational distributed lag framework. Market activities reveal that the retail, wholesale, slaughter, and feeder market levels are highly interrelated. When these interrelationships are accounted for in an empirical model, the estimated structural parameters and various elasticities provide a better understanding of forces determining demand and supply in the beef industry. Also, such knowledge can be a valuable asset in evaluating the impact of exogenous shocks and government policies on the beef industry and in conditional forecasting.

Previous models of the U.S. beef industry have addressed several of these levels (Arzac and Wilkinson; Kulshreshtha and Wilson; Crom; Langemeir and Thompson; Freebairn and Rausser). However, specification of the maintained hypotheses and methodologies has differed. A major reason is the dynamic nature of the cattle and meat markets. Dynamics of supply and demand in these sectors result from producer and consumer expectations, biological production lags, technology, weather, and institutional lags in the market channel. Though certain economic variables are recognized in these markets (consumption and production, quantities of substitutes, income, feed costs, marketing costs), theory is not clear as to the proper specification of the dynamic lag structure. When the whole marketing system is considered, different time periods (weekly, monthly, quarterly, annually) may even show differences as to how prices are actually established at the packer-wholesale level and at the retail level. In this paper we estimate a rational lag structure of the primary and derived levels of the beef market. We argue that the consumer has an important vote in the entire price structure of the demand side of the market. This is particularly so within a one-year time period. Coupled with primary and derived supply factors, beef supplies and prices at all levels of the market chain are then determined.

Gary W. Brester is a Research Associate and John M. Marsh is an Associate Professor in the Department of Agricultural Economics and Economics at Montana State University.

Journal Series No. 1418 of the Montana Agricultural Experiment Station. The authors are grateful for the helpful comments of the anonymous Journal referees.

Western Journal of Agricultural Economics, 8(1), 1983, pp. 34–49

Methodological Considerations

Jorgenson's rational distributed lag structure served as the basis for estimating the dynamic equations. Mathematically, Jorgenson's model can be expressed as:

$$Y_t = R(L)X_t = \frac{\alpha(L)}{\lambda(L)}X_t + e_t \qquad (1)$$

where the rational lag function $R(L)X_t$ is characterized by the ratio of two polynomials $\alpha(L)$ and $\lambda(L)$, which have no characteristic roots in common. The lag operator L implies that $L^kX_t = X_{t-k}$. Multiplying both sides of equation (1) by $\lambda(L)$ yields

$$\lambda(L)Y_t = \alpha(L)X_t + \lambda(L)e_t \qquad (2)$$

so that

$$(1 + \lambda_1L + \ldots + \lambda_nL^n)Y_t = (\alpha_0 + \alpha_1L_1 + \ldots + \alpha_mL^m)X_t + e_t^* \qquad (3)$$

where

$$e_t^* = \lambda(L)e_t = \sum_{i=0}^{n} \lambda_ie_{t-i}$$

and is autocorrelated. Thus, the rational lag structure of equation (2) is reduced to an n^{th} order difference equation with an n^{th} order moving average error structure. Jorgenson concludes that any arbitrary lag function can be approximated to any desired degree of accuracy by a rational lag function with sufficiently high values of m and n.

Burt indicates there are problems of specifying and estimating an unknown error structure in dynamic models. Consequently, nonstochastic difference equations may be more appropriate in the measurement of agricultural supply response than stochastic difference equations. Marsh (1983) also justifies this method in the nonlinear estimation of seasonal cattle prices. The delineation of stochastic versus nonstochastic equations depends on the manner in which the lagged dependent variable enters the set of regressors. In equation (3), the observed values of the lagged dependent variable are used and, thus, they contain a stochastic component.[1] The nonstochastic difference equation uses the expected value of the lagged dependent variable. Incorporating this idea into a simple Koyck equation yields:

$$Y_t = \alpha + \beta X_t + \lambda E(Y_{t-1}) + \rho u_{t-1} + u_t \qquad (4)$$

where $E(Y_{t-1})$ is the expected value of Y_{t-1} and u_t has the classical properties. Equation (4) is nonstochastic in that successive iterations yield $E(Y_t)$ as a function of only the historical value of X_t, and $E(Y_{t-1})$ is strictly an exogenous variable if the disturbance term is autocorrelated.[2]

The lagged expectation of the dependent variable and/or the autocorrelated error structure produces some estimation problems for ordinary least squares (OLS) because of the introduction of nonlinearities in the parameters. Therefore, the nonstochastic difference equations in the model are estimated by least squares (maximum likelihood under the assumption of normality) from a modified Marquardt nonlinear least squares algorithm.

The Economic Model

The following equations represent the economic relationships of the beef model. Table 1 gives the definitions of the variables.

Retail Sector

(a) Retail price

$$P^{rb} = f_1[Q^{fed}, Q^{nfed}, Y, Q^{pk}, Q^{ply}, E(P^{rb} - j)]$$

[1] A random variable Y_t is defined as $Y_t = E(Y_t) + u_t$, where $E(Y_t)$ is the expected value and u_t is a random disturbance term with zero mean, and $E(u_tu_{t-j}) = 0$ for $t \neq j$ and $= \sigma^2$ for $t = j$.

[2] The $E(Y_{t-j})$ are unobservable variables but are defined for given values of the parameters in equation (3). In the iterative solution of the nonlinear least squares algorithm, the observed Y_{t-j} are used as initial estimates of $E(Y_{t-j})$, and the resulting estimates of λ_j and α_j are used as the starting values of the respective parameters (Burt, pp. 7–10).

TABLE 1. Definitions of the Endogenous and Exogenous Variables Used in the Beef Model Estimation.[a]

	Endogenous Variables
P^{rb}	= weighted average price of retail beef for choice table cuts, yield grade 3, cents/lb.
Q^{fed}	= per capita consumption of fed beef, pounds on a carcass weight basis.
Q^{nfed}	= per capita consumption of nonfed beef, pounds on a carcass weight basis.
P^{car}	= the price of choice-grade carcass beef, yield grade 3, cents/lb. at Chicago.
M^{c-r}	= carcass-to-retail marketing margin, cents/lb.
M^{f-c}	= farm-to-carcass marketing margin, cents/lb.
P^{sl}	= price of choice slaughter steers, 900–1,100 lbs., Omaha, cents/lb.
Q^{dpl}	= placements of cattle on feed in the 23 major cattle feeding states, thousands of head.
P^{fc}	= price of choice feeder steers, 600–700 lbs. Kansas City, dollars/cwt.
Q^{spl}	= placements of cattle on feed in the 23 major cattle feeding states, thousands of head.
P^{gsl}	= price of good-grade slaughter steers, 900–1,100 lbs., Omaha, cents/lb.
Q^{sfd}	= number of commercially slaughtered fed cattle, thousands of head.
Q^{snfd}	= number of commercially slaughtered nonfed cattle, thousands of head.
INV	= January 1 inventory of feeder cattle, calves and yearlings, thousands of head.
	Exogenous Variables
Y	= per capita real disposable income, dollars.
Q^{pk}	= per capita consumption of pork, pounds on a carcass weight basis.
Q^{ply}	= per capita consumption of poultry, pounds.
ADW^{fed}	= average dressed carcass weight of fed slaughter, pounds.
ADW^{nfed}	= average dressed carcass weight of nonfed slaughter, pounds.
P^{cby}	= price of carcass by-products, portion of gross carcass value attributed to fat and bone, cents/lb.
W^{mp}	= average real hourly earnings of production workers in the meat products industry, dollars.
PK	= packaging costs for intermediate materials, supplies, and components—including materials for containers and supplies, and processed fuels, Wholesale Price Index (1967 = 100).

TABLE 1. Continued.

	Exogenous Variables
P^{fby}	= price of farm by-products, portion of gross farm value attributed to edible and inedible by-products, cents/lb.
W^{pp}	= average real hourly wages of production workers in meat packing plants, dollars.
R	= price of refined oil products, Wholesale Price Index (1967 = 100).
t	= trend, 1, 2, . . ., n.
P^c	= price of #2 yellow corn, Chicago, dollars/bushel.
D	= dummy or binary shifter.

[a] Sources: USDA Livestock and Meat Situation, Agricultural Statistics, BLS Monthly Labor Review.

(b) Retail supply

$$Q^{fed} = Q^{sfd} \cdot ADW^{fed}$$
$$Q^{nfed} = Q^{snfd} \cdot ADW^{nfed}$$
$$j = 1, 2, \ldots, n$$

Carcass Sector

(c) Carcass price

$$P^{car} = f_2[P^{rb}, M^{c-r}, P^{cby}, E(P^{car} - j)]$$

(d) Carcass-retail margin

$$M^{c-r} = f_3[W^{mp}, PK, t, E(M^{c-r} - j)]$$

Slaughter Sector

(e) Slaughter price

$$P^{sl} = f_4[P^{car}, M^{f-c}, P^{fby}, E(P^{sl} - j)]$$

(f) Fed slaughter supply

$$Q^{sfd} = f_5[Q^{spl}, P^{sl}, P^c, E(Q^{sfd} - j)]$$

(g) Nonfed slaughter supply

$$Q^{snfd} = f_6[P^{fc}, P^{gsl}, P^c, E(Q^{snfd} - j)]$$

(h) Farm-carcass margin

$$M^{f-c} = f_7[W^{pp}, R, t, E(M^{f-c} - j)]$$

Feeder Sector

(i) Feeder cattle inventories

$$INV = f_8[P^{fc}, P^c, E(INV - j)]$$

(j) Feeder placement supply

$$Q^{spl} = f_9[INV, P^{fc}, P^{gsl}, E(Q^{spl} - j)]$$

(k) Feeder placement demand

$$Q^{dpl} = f_{10}[P^{fc}, P^{sl}/P^c, E(Q^{dpl} - j)]$$

(l) Market identity

$$Q^{spl} = Q^{dpl}$$

All prices, wages, income, and margins are deflated by the Consumer Price Index (CPI) (1967 = 100). Deflating all market levels by the CPI is appropriate when margins are specified (Foote). The operator E represents the lagged expectations of the dependent variables. Subscripts on the independent variables are omitted; however, it is implied that distributed lags exist. Usually some experimentation was necessary to discover the final structure.[3]

The specification of the model is based on economic theory and knowledge of the commodity sectors. The annual sample data are for the period 1960 to 1980 and are obtained from secondary sources. There were no specific problems with the data in relation to the variables defined. The only potential problem was with carcass price. It is recognized that pricing in the dressed beef trade is characterized by negotiations and formulas, where a large percentage of the output comprises boxed beef (USDA). However, in the sample, carcass price is highly correlated with formula and boxed beef prices. This would be expected since, over the long term, the wholesale trade is subject to consumer influence.

Predicted values of several endogenous variables were substituted for their observed values in the right-hand side of certain structural equations. They were estimated by instrumental variables, i.e., a two stage least squares procedure to account for joint dependency in the system. These variables included consumption of fed and nonfed beef, carcass-retail and farm-carcass margins, and prices of feeder cattle and good-grade slaughter cattle. Such procedures are valid in rational distributed lag models when the goodness of fit in the instrument equations is satisfactory (Hanssens and Liu). Where retail price, carcass price, and slaughter price were entered as regressors in other equations, this procedure was not followed. Equations (a), (c), and (e) describe these variables, and their actual values were assumed to be independent of the error structure in the equations in which they were entered.

Based on an annual time period, primary demand at the retail level is assumed to represent final market clearance and equilibrium conditions. Choice retail beef prices, equation (a), are hypothesized to be a direct function of fed beef consumption and real disposable income. The variables nonfed beef consumption, pork, and poultry consumption serve as substitute meats. The lagged expectation of retail prices not only implies distributed lags on the independent variables, but indirectly may reflect consumer habit formation (Pollak).

It might be argued that retail beef price is merely carcass price plus a margin. However, over the course of one year, carcass prices are not autonomous, but rather are subject to the economic forces that govern final demand. For example, changes in consumer expectations, real income, and quantities of beef substitutes impact retail prices, which in turn influence carcass prices in the packer-wholesaler trade. Consequently, all remaining price relations in this model are considered derived. In the very short term, carcass price plus a margin, or perhaps formula prices, may be more dominant since economic changes at the retail level have not had sufficient time to be passed down through the market channel (USDA).

The retail supply of fed and nonfed beef is defined on a carcass weight basis. Each is a derived relation based on fed and nonfed slaughter multiplied by their respective dressed carcass weights. Since beef stocks and imports are a small percentage of domestic production, per capita supply and consumption for each class are assumed nearly equal.

[3] In the rational lag model it may be convenient initially to specify the same lag on the independent variables as the order of lag on the difference equation. The final order lag on the latter involves some regression experimenting since theory may offer little help. Some of the higher order lags on the rational lag structure may be truncated if not significant.

Carcass prices are considered derived and therefore are partly determined by retail prices, equation (c). They implicitly reflect quantities of meat supplies since the latter are included in the retail equation. Other variables considered important are the value of carcass by-products and carcass-retail marketing costs, the latter a function of wages and packaging costs, equation (d).[4] Tomek and Robinson (pp. 130–33) indicate that increases in marketing costs reduce the derived demand for a commodity. Increases in the price of by-products would tend to increase the value of a carcass and hence its price, since by-products are crucial in covering packer slaughter costs and profit (Doane).

In the slaughter sector choice slaughter prices (equation (e)) and fed slaughter and nonfed slaughter supplies (equations (f) and (g)) are also derived relations. Slaughter prices depend upon carcass prices since they are expected to influence packer bids for cattle entering the plants. Supply implicitly affects slaughter prices because of its initial specification in the retail price equation. Slaughter prices are also determined by the farm-carcass marketing costs (equation (h)) and farm by-product values. With increases in both, the former is expected to reduce slaughter price, whereas the latter is expected to bid up slaughter price.

Slaughter cattle supplies were separated into fed and nonfed sectors since marketing decisions by producers differ between the two (Nelson and Spreen). The supply of fed cattle slaughter is hypothesized to be a function of the quantity of cattle placed on feed and expected choice slaughter steer and corn prices. Nonfed slaughter is a function of variables representing the opportunity costs of producing feedlot beef. A priori, it is expected that increases in choice feeder prices would decrease supplies of cattle going into nonfed slaughter. Price increases for good-grade slaughter cattle and corn are expected to increase the quantity of cattle marketed as nonfed slaughter. With their respective dressed carcass weights, fed beef and nonfed beef slaughter directly determine retail fed and nonfed beef supplies (equation (b)).

The feeder cattle sector consists of feeder cattle inventory, equation (i), and feeder placement supply and demand, equations (j) and (k). The inventory function is treated as primary supply while the latter two are assumed to be derived supply and demand relations, respectively. Inventories of feeder cattle stem from the basic cow-calf and cow-yearling production process, each of which is hypothesized to be determined by feeder cattle prices and feed prices. Inventories then serve partially to explain supplies of cattle offered to feedlots, along with feeder cattle prices and the price of good-grade slaughter cattle. A priori, higher feeder cattle prices would encourage additional supplies offered to feedlots. Conversely, higher prices of good-grade slaughter steers would cause a larger number of feeders to circumvent the feedlot and lead to greater quantities going into the nonfed sector.

Feeder placement demand reflects economic variables in both the input and output segments of the market. For example, higher feeder cattle prices increase acquisition costs and would be expected to reduce quantity demanded. An increase in choice slaughter prices relative to corn prices (steer-corn price ratio) can imply higher feedlot profits and translates into increased demand for cattle placements. Implicitly, feeder cattle supply and de-

[4] The marketing margin variables used in this model are determined by market cost factors so as to capture their effects as shifters of derived carcass and slaughter cattle prices. The values of the margins, predicted from equations (d) and (h), are used in the right-hand side of these equations, rather than the cost factors, so as to preserve degrees of freedom. Also, in nonlinear least squares having fewer parameters reduces the problem of iterative convergence in the algorithm.

TABLE 2. Regression Results of the Retail Price, Carcass Price, and Carcass-Retail Marketing Margin Equations.[a]

		Variables										Statistics[b]		
Equations	Intercept	Y_t	Q_t^{fed}	Q_t^{nfed}	Q_t^{pk+ply}	$E(P_{t-1}^{rb})$	P_t^{rb}	M_t^{c-r}	P_t^{cby}	W_t^{mp}	PK_t	$\bar{R}^2$	S_y	D-W
P^{rb}	64.211	.019	−.532	−.914	−.164	.751						.918	1.928	2.60
	(7.068)	(8.231)	(−7.002)	(−10.031)	(−1.752)[c]	(12.781)								
P^{car}	9.425						.422	−.689	12.698			.941	.950	1.59
	(2.917)						(8.660)	(−9.268)	(4.509)					
M^{c-r}	−76.141									26.744	.261	.699	2.21	1.52
	(−5.106)									(5.782)	(3.375)			

[a] The asymptotic t-ratios are in parentheses below each coefficient. All variables but one are significant at the 95 percent level.
[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
S_y = standard error of the estimate.
D-W = Durbin-Watson statistic.
[c] Significant at about the 90 percent level.

mand interact to determine feeder cattle price.

Empirical Results

The statistical results of the price, margin, and feeder demand regression equations are presented in Tables 2 and 4, while those of the inventory and supply equations are shown in Tables 5 and 6. Table 3 presents the price flexibilities and elasticities specific to all the equations.

Retail Prices

The final retail price equation was estimated as a first-order nonstochastic difference equation (Table 2).[5] This result indicates that the rational lags with respect to each of the independent variables decline geometrically, the rate of decline being determined by $\lambda = .751$.[6] Higher order lags on the difference equation, implying polynomial shaped rational lags, were tried but were statistically insignificant.

The model reveals the importance of per capita disposable income. The estimated short-run price flexibility with respect to income is .613 (Table 3), and compares favorably to Walters, Moore, and Neghassi's estimate of .86 and also their reported estimates from other studies. The estimated long-run income flexibility of 2.46 is considerably larger, indi-

[5] The nonstochastic difference equation coefficients are interpreted as "normal" changes since unusual or chance factors are netted out. Also, an autoregressive disturbance structure implied in this rational lag equation was tested and found to be insignificant. This could indicate a lack of serious model misspecification and the fact that annual data tend to exhibit less serial correlation than do data for shorter units of time.

[6] In a simple first-order difference equation of $Y_t = \beta X_t + \lambda Y_{t-1}$, it is implied that a distributed lag exists on X_t because of Y_{t-1}. Thus, the cumulative lag effects of X_t are $\beta(1 + \lambda + \lambda^2 + \lambda^3 + \ldots)\Delta X_t$, which is useful for measuring intermediate and long-term effects.

TABLE 3. Estimates of the Short- and Long-Run Price Flexibilities and Supply Elasticities of the Price and Supply Beef Model.[a]

Equations	P^{rb}	Y	Q^{fed}	Q^{nfed}	Q^{pk+ply}	P^{car}	M^{c-r}	P^{cby}	P^{sl}	M^{f-c}	P^{fby}	P^{fc}	$\frac{P^{sl}}{P^{c}}$	INV^{fc}	P^{gsl}	Q^{spl}	P^{c}	$\frac{P^{fc}}{P^{gsl}}$
P^{rb}		.613	−.425	−.304	−.180													
		(2.459)	(−1.705)	(−1.219)	(−.723)													
P^{car}	.884						−.439	.338										
	—						—	—										
P^{sl}						.925				−.091	.102							
						—				—	—							
Q^{dpl}												−.622	.342					
												(−29.614)	(16.29)					
Q^{spl}												.411		1.128	−1.02			
												(3.841)		—	(−9.537)			
Q^{sfed}									−.192							.956		
									—							—		
Q^{snfed}																	.424	−1.25
																	(.920)	(−2.71)
INV												.053					−.051	
												(3.317)					(−1.552)	

[a] The top number in each row represents the short-run effects evaluated at the means of the variables. The long-run effects are in parentheses where applicable and are calculated by dividing the short-run coefficients by one minus the appropriate difference equation coefficient.

TABLE 4. Regression Results of the Slaughter Price, Feeder Placement Demand, and Farm-Carcass Marketing Margin Equations.

Equations	Intercept	Variables[a]											Statistics[b]		
		P^{car}_t	M^{f-c}_t	P^{fby}_t	P^{fc}_t	P^{fc}_{t-1}	P^{fc}_{t-2}	$\frac{P^{sl}_t}{P^c_t}$	$E(Q^{dpl}_{t-1})$	W^{pp}_t	R_t	t	$\bar{R}^2$	S_y	D-W
P^{sl}	1.750	.577	−.426	.417									.957	.526	1.59
	(1.371)	(14.003)	(−3.977)	(3.716)											
Q^{dpl}	7,280.3				−364.65	−236.75	100.4	364.45	.979				.952	718.37	2.31
	(5.68)				(−3.954)	(−3.385)	(1.828)[c]	(7.343)	(31.338)						
M^{f-c}	−27.032									10.928	.034	−.730	.864	.55	2.04
	(−2.330)									(2.960)	(4.170)	(−4.698)			

[a] The asymptotic t-ratios are in parentheses below each coefficient. All variables but one are significant at the 95-percent probability level.
[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
S_y = standard error of the estimate.
D-W = Durbin-Watson statistic.
[c] Significant at the 90-percent level.

TABLE 5. Regression Results of Feeder Cattle Inventory and Feeder Placement Supply Equations.

Equations	Intercept	Variables[a]												Statistics[b]		
		D^{1974}	INV_t	P^{gsl}_t	$E(Q^{spl}_{t-1})$	P^{fc}_t	P^{fc}_{t-1}	P^{fc}_{t-2}	P^{fc}_{t-3}	P^c_{t-1}	$E(INV_{t-1})$	$E(INV_{t-2})$	u_{t-1}	$\bar{R}^2$	S_y	D-W
INV_t	−4,084.5						99.782	114.26	88.798	−1,923.1	1.734	−.767	−.827	.996	255.89	2.66
	(−15.311)						(6.118)	(4.195)	(4.454)	(−17.037)	(42.97)	(−21.569)	(−6.058)			
Q^{spl}_t	13,541.0	−3,893.2	.483	−923.11	.893	324.53								.906	1,104.4	1.62
	(4.779)	(−2.817)	(3.817)	(−5.541)	(10.223)	(3.010)										

[a] The asymptotic t-ratios are in parentheses under each coefficient. All variables are significant at the 95-percent level.
[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
S_y = standard error of the estimate.
D-W = Durbin-Watson statistic.

TABLE 6. Regression Results of Fed Slaughter and Nonfed Slaughter Supply Equations.

	Variables[a]								Statistics[b]		
Equations	Intercept	D^{1974}	$\frac{P^{fc}_t}{P^{gsl}_t}$	P^c_t	$E(Q^{snfd}_{t-1})$	Q^{spl}_t	Q^{spl}_{t-1}	P^{sl}_t	$\bar{R}^2$	S_y	D-W
Q^{sfd}_t	5,638.8					.347	.637	−159.96	.989	421.59	2.21
	(4.156)					(5.580)	(11.378)	(−3.695)			
Q^{snfd}_t	15,276.0	−1,725.7	−13,000.0	3,851.7	.539				.952	710.83	1.73
	(4.518)	(−1.819)[c]	(−5.979)	(4.630)	(11.870)						

[a] The asymptotic t-ratios are in parentheses below each coefficient. All variables are significant at the 95-percent level except one.
[b] $\bar{R}^2$ = adjusted multiple R-squared statistic.
S_y = standard error of estimate.
D-W = Durbin-Watson statistic.
[c] Significant at the 90-percent level.

cating a period of time sufficiently long for consumers to completely adjust to a change in income.[7] The geometric lag effect of income dissipates in about seven years.

The negative response of choice retail prices to changes in fed beef consumption indicates a movement along the inverse demand or price curve. The short-term fed consumption price flexibility of −.425 compares favorably with Arzac and Wilkinson's inverse of −.54. Likewise, as demand shifters, the market substitutes for fed beef have an inverse effect on price. Nonfed beef (ground and processed) is a close substitute and has an estimated short-run price flexibility of −.304, which is consistent with Langemeir and Thompson's estimate of −.380 and Arzac and Wilkinson's inverse nonfed price elasticity of −.340. The model also indicates that a 10 percent increase in nonfed beef consumption has a long-term effect of decreasing the price of fed beef by approximately 12 percent, compared to 17 percent for an increase in fed beef consumption.[8] The geometric lag effect of both classes of consumption phases out in about five years.

In a preliminary analysis, the t-values from regressions of two other substitutes, pork and poultry, indicated that these variables were not significantly different from zero. One explanation for their poor

[7] The long-term dynamic effects should be interpreted with caution. If we assume minimal specification errors in the model, then the theoretical restrictions on the long-term response coefficients result from the assumption of a one-time change in the independent variable with all other variables remaining constant.

[8] In this equation, consumption of beef imports was entered as a separate regressor and was statistically insignificant. It was also added to domestic nonfed beef consumption with little success in yielding significant results. Historically, imports have only been 6 to 8 percent of U.S. beef consumption, but its insignificance in either form above is not consistent with the findings of some other studies (Freebairn and Rausser; Houck).

statistical performance was high collinearity. The two variables were then added together to form an aggregate substitute, (Q^{pk+ply}). However, it is significant only at about the 90 percent probability level. Estimated short- and long-term price flexibility coefficients for the aggregate variable show that its competitive effects are about 60 percent of the effect of nonfed beef. Their distributed lag effects dissipate in about two years.

Carcass Demand Sector

Predicted values of the carcass-retail margin were used as an instrumental variable in the carcass price equation. This was due to the probable joint dependency between the observed margin variable and carcass prices. Further testing of the model later confirmed this hypothesis. The statistical results of the margin and carcass price equations are presented in Table 2.

Carcass-Retail Marketing Margin

This equation was estimated as a function of wages and packaging costs. The statistical results show that the margin increases whenever these components of processing costs increase, although it is difficult to determine the precise impact of packaging costs since the variable is defined as a price index. Alternative specifications were also tried using such variables as an index of transportation costs and trend. However, each of these variables was insignificant. Likewise, experimentation with dynamic forms yielded less satisfactory results. This was not too surprising given the ability of the carcass-retail marketing sector to adjust their price and output levels within a given year.

The adjusted multiple R-squared statistic of .69 is quite low. The reason for this relatively poor fit may be two-fold. First, the proper data necessary to estimate this equation were not available, and some specification error was likely. Second, it may be that some of the variation in the carcass-retail marketing spread could not be explained statistically because of the imperfectly competitive market structure and its associated nonprice competition aspects.

Carcass Price Equation

Carcass price was directly estimated as a static function, although it is implicitly dynamic by virtue of the rational lags in the retail price equation. All signs of the coefficients are as expected. Experimentation with direct distributed lag specifications yielded equations with inferior statistical results. The structure and market interactions at the carcass and wholesale level suggest that carcass prices in previous years do not affect contemporaneous prices. One major reason is the short-term nature of decision making in the processing sector: the market relies upon negotiated and formula pricing, and decisions about bid and offer prices between processors and retailers may occur on a weekly and in some cases on a daily basis.

The price of retail beef is highly significant in determining carcass price. This result was expected since the demand price for carcasses is greatly influenced by the equilibrium retail price of the commodity. A 10 cent per pound increase in the price of retail beef increases carcass prices by 4.2 cents per pound. The short run price flexibility is .884.

The negative sign of the carcass-retail marketing margin coefficient indicates that a one cent per pound increase in the margin reduces carcass prices by nearly .7 cents per pound; or the price flexibility coefficient suggests that a 10 percent increase in the margin reduces carcass prices by 4.4 percent. Marsh's (1977) estimate suggests that a 10 percent increase in the margin reduces carcass prices by 3.0 percent.

Meat processors usually depend upon by-product values to cover processing costs and profit margins. At this level, the by-products which accrue to processors are those extracted from carcasses. The carcass by-product variable indicates a significant relationship, as a 10 percent increase in carcass by-product values increases carcass prices by 3.4 percent.

Slaughter Demand Sector

Farm-Carcass Marketing Margin

The farm-carcass marketing margin was estimated as a static function of wages and energy costs, the latter defined as a price index for refined oil products (Table 4). Wages constitute a large portion of the variable costs in meat packing plants, and, as expected, the margin increases as wages increase. Likewise, increases in energy costs widened the margin although it was difficult to determine the exact marginal impact of energy since a price index was used as a proxy for these costs.

A trend variable was also found to be significant, and the negative sign of the trend coefficient indicates there may have been decreasing cost changes occurring in the packing industry. For example, the introductions of boxed beef and single-level assembly line processing during the 1960s undoubtedly accounted for decreased slaughtering costs and increased processing efficiency.

Choice Slaughter Price

The final direct estimation of slaughter price, equation (e), was also static (Table 4). However, the geometric rational lag structure of retail prices imposes dynamics via carcass price behavior. The absence of a direct rational lag structure at the slaughter level might be expected given that packer pricing decisions are more short-term in nature. This was confirmed when attempts to estimate the equation as a difference equation, with lags on the regressors, were unsuccessful.

The price of carcasses is highly significant in explaining the variation in slaughter prices, indicating that the sale price of carcasses dictates the bid prices packers offer for fat cattle. This is confirmed with an estimated price flexibility of .925. In fact, under formula pricing, some packers adjust the Yellow Sheet price for slaughter costs (including profit) to arrive at a live cattle price (USDA, p. 8).

The predicted values of the farm-carcass margin were used as an instrumental variable in the slaughter price equation. Theoretically, there was potential joint dependency between slaughter prices and the margin. The negative sign of the farm-carcass margin coefficient is as expected, showing that a one-cent increase decreases slaughter price by slightly less than one-half cent per pound. As discussed above, meat packing plants also depend upon the sale of by-products to cover slaughter costs and profit margins. The positive coefficient for this variable, which represents by-product allowances specific to the slaughter activity, indicates that packers bid higher prices for slaughter cattle as by-product values increase (about .42 cents per pound for a 1.0 cent per pound increase).

Fed Beef Slaughter Supply

Fed beef slaughter supply (equation (f)) was estimated as a function of contemporaneous and first-order lagged values of the quantity supplied of feeder cattle, and the contemporaneous price of choice grade slaughter cattle, Table 6. The placement supply variable (Q^{spl}) entered the equation as estimated in the feeder placement supply equation in Table 5. The statistical results reveal that a 1,000 head increase in the number of feeder cattle placements increases the number of fed cattle slaughtered by 347 head. A one-period lag on the placement variable was also included, indicating that a 1,000 head increase in period $t - 1$ results in a 637 head increase in the number of fed beef slaughtered in period t. This result reflects the fact that animals placed on feed in the latter part of the year may not be slaughtered until the following year. The sum of the estimated coefficients is approximately one since all animals placed on feed net of death loss will be slaughtered.

Most supply equations include own price as a principal regressor, and its sign is expected to be positive. However, price performs a slightly different role in this equation since only a certain quantity of fat cattle will be slaughtered in a given year, even if the price of fat cattle increases dramatically. Fed beef is usually slaughtered within a weight range of 900 to 1,300 pounds, and the specific slaughter weight may depend upon expected prices. When slaughter prices are high, prices in the future are also expected to be high, which may delay cattle marketings to heavier slaughter weights. Myers, Havlicek, and Henderson refer to this phenomenon as "reservation demand." In the fed cattle market, placements on feed increase seasonally in the third and fourth quarters of the year, leading to seasonally large slaughter in the fourth and first quarters. Thus, the negative sign on the estimated price coefficient indicates that a contemporaneous increase in the price of fat cattle in the latter part of year t results in feeding cattle to heavier weights in period $t + 1$. Beef slaughter supply equations estimated by both Tryfos and Reutlinger support this hypothesis.

Nonfed Beef Slaughter Supply

Nonfed beef slaughter, equation (g), was estimated as a function of a binary shift variable, the ratio of contemporaneous prices of feeder cattle to those of good-grade slaughter cattle, and the contemporaneous price of corn (Table 6). The dynamics were estimated as a first-order nonstochastic difference equation. Higher order lags on the difference equation and the rational lag structure were tried but were statistically insignificant.

A dummy variable was included for the year 1974 because of the market irregularities that occurred during the 1973–74 period.[9] They included the Nixon Administration price freeze on beef and its subsequent delayed removal, the 1973 consumer beef boycott, and a strike by the commercial trucking industry in early 1974. The variable's negative sign reflects their impact and indicates nonfed slaughter is reduced in relation to what the equation would normally have predicted for that year.

The sign of the price ratio is negative. This implies that an increase in the price of feeder cattle relative to the price of good slaughter cattle results in a decrease of nonfed slaughter. Specifically, the estimated coefficient shows that a ten cent per hundredweight increase in the ratio decreases nonfed slaughter by 1.3 million head. The size of the short-run and long-run elasticities of supply (-1.25 and -2.71, respectively) reveals the sensitivity of the nonfed beef sector to its opportunity costs of production.

The price of corn is highly significant

[9] The predicted values of the nonfed slaughter variable, multiplied by the average dressed weights of nonfed slaughter, were divided by population to obtain the predicted values of per capita nonfed beef consumption used in the retail equation discussed earlier. Technically, the predicted 1974 observation for nonfed beef consumption used in the retail price equation is jointly dependent with that equation's error structure. The dummy variable used in the nonfed beef supply equation resulted in the predicted value of the dependent variable being equal to its observed value. A solution to this problem would have been to omit all of the 1974 observations in the retail price equation by using a dummy variable. However, from an inspection of the residuals of the retail equation as was specified earlier in this paper, it was concluded that the year 1974 was not an extreme observation. Therefore, the benefit of using a dummy variable for 1974 in the retail price equation would probably have been minimal when compared to the costs of losing another degree of freedom.

and positively correlated with the dependent variable. The short-run supply elasticity coefficient indicates that a 10 percent increase in the price of corn results in a 4.2 percent increase in nonfed slaughter, while the long-run supply elasticity shows a 9.2 percent increase. This result is expected since an increase in feed prices reduces feedlot profitability and allows producers of grass fed beef and meat packers to competitively bid for feeder cattle.

The estimated coefficient associated with the difference equation term is relatively small (.539), indicating that the distributed lag effects of the independent variables dampen rather quickly. For example, the geometric lag effects of both the price ratio and corn price variables dissipate around the sixth time period. This is not surprising since the time required to divert resources between fed and nonfed production would be considerably shorter than the expected length of a cattle cycle.

Feeder Sector

Feeder Cattle Inventories

Feeder cattle inventory was estimated as a second-order difference equation with first-order negative serial correlation. The dynamics were stable and the equation possessed complex roots, indicating an oscillatory pattern converging towards an equilibrium (Griliches, p. 28). The final rational lag structure is a three-period lag on the price of feeder cattle and a one-period lag on the price of corn. The results of this equation confirm the fact that cyclical behavior is more pronounced at the feeder market level than at the level of wholesale and retail markets (Franzmann and Walker). The statistical results are given in Table 5.

The function took on a polynomial rational lag structure by virtue of the difference equation parameters. The distributed lag structure indicates that inventories tend to peak in seven years because of a change in feeder price and peak in six years from a change in corn price. The effects of both variables dissipate at the end of two cattle cycles (20 years). The positive signs on the lags of feeder prices meet a priori expectations, that is, a build up in cow herds and, hence, in feeder inventories, when prices are expected to increase. The small short-term elasticity (.053) compared to the large long-term elasticity (3.317) is indicative of the biological limits imposed on short-run response over the course of a cattle cycle.

Corn price displays short-term behavior similar to that of feeder cattle prices, although the long-run feed price elasticity is considerably smaller (−1.552). Again, the expected effect of changes in feed costs on feeder cattle inventories can only be adjusted by increasing or decreasing the cow herd base. Its smaller long-term impact compared to feeder prices probably demonstrates the greater weight of output prices compared to input costs in affecting production adjustments within a cattle cycle.

Feeder Placement Demand

The placement of cattle on feed, equation (k), was estimated as a first-order nonstochastic difference equation. The price of feeder cattle resulted in a second-order rational lag, and the slaughter steer-to-corn price ratio remained contemporaneous. Different order lags on the difference equation and the rational lag structure produced inferior results. The statistical results of the equation are reported in Table 4.

The distributed lag effect of the feeder price variable indicates cattle feeders' expectations of future prices are based on past price behavior. Its negative impact is consistent with demand theory. The large difference between the short-term and long-term price flexibility coefficients indicates that cattle feeders tend to more fully adjust demand to price changes over time. Also, the large difference equation coefficient (.979) implies large long-run price flexibility coefficients and a lengthy geometric lag. One reason may be that feeder placement demand is interrelated with the long-term cattle cycle. Another may relate to risk management by cattle feeders. That is, feeders may be hesitant in making rapid adjustments to recent price changes because of expectations of continuing changes in input and output prices.

The contemporaneous steer-corn price ratio reflects economic conditions in the slaughter and feed grain markets. The sign of this variable is positive, indicating a larger demand for cattle placements when profits increase. The short-term price flexibility is .34. However, the profit response is large over the long-run since cattle feeders are able to adjust plant size, management, and technology.

Feeder Placement Supply

Feeder placement supply, equation (j), was also estimated as a first-order nonstochastic difference equation. A binary shifter for 1974 was also added to the equation for reasons stated earlier. The statistical results are presented in Table 5.

The negative coefficient of the dummy variable indicates its impact was significant in reducing feeder cattle placements. Because of the institutional constraints, the price of feeder cattle decreased from 1973–74 by approximately 35 percent, thus increasing the quantity supplied of young feeders to nonfed production. The data show that the number of nonfed cattle slaughtered in 1974 increased by 67 percent from 1973.

The January 1 inventory of feeder cattle (INV) measures the physical limitation of the number of calves and yearlings which are supplied to feedlots in a given year. The positive sign of the coefficient indicates that greater quantities of feeder cattle are supplied to feedlots when inventories increase. For example, each 1,000 head increase in inventory results in an extra 483 head placed in feedlots.

The estimated coefficient of the price of feeder cattle indicates that a price increase of one dollar per hundredweight increases the quantity supplied of feeder cattle by 324 thousand head. The coefficient of the price of good-grade slaughter cattle is negative. This supports the earlier hypothesis that a greater amount of feeder cattle circumvent feedlots and enter the marketing system as nonfed beef when the price of nonfed beef increases.

The distributed lag effects of both price variables on the quantity supplied of placements are characterized by a geometrically declining lag structure. Polynomial-shaped rational lags were tested but were statistically insignificant. The relatively large size of the difference equation coefficient implies an adjustment process occurring over many periods. As with the placement demand equation, this long-term adjustment is tied in with the cattle cycle and secular changes in weather, forage, and feed conditions. It also reflects feeder cattle producers' expectations of price and risk and their subsequent marketing decisions in the fed and nonfed cattle sectors.

Concluding Remarks

A dynamic econometric model using rational distributed lags estimated the price, demand, and supply structure of the primary and derived production and marketing levels of the U.S. beef industry. The estimated coefficients of each equation were employed to calculate the short- and long-run structural effects; the long-run effects were particularly useful in analyzing distributed lag patterns of the endogenous variables in the beef market.

Several inferences are apparent from the analysis. It is evident that, based on annual data, certain behavioral equations are of a dynamic structure. Primary retail price and primary feeder inventories possess a rational lag structure that indirectly affects the derived levels of the market. The feeder cattle inventory equation was characterized as a polynomial rational lag structure, reflecting the economic and biological cattle cycle. Retail price was a geometric rational lag structure, partly reflecting consumer expectations and habit formation. Other remaining dynamic equations were directly estimated as a geometric rational lag structure. The time period of dissipation was a direct function of the nonstochastic difference equation parameters and the estimated coefficients of the independent regressors. Marketing costs were also crucial because of their negative correlation with derived market prices.

The results of the study should be interpreted in view of the fact that perfect competition is not the actual market structure of the beef industry, particularly in the higher order markets. Nevertheless, the empirical evidence indicates that consumer behavior is critical in establishing the structure of primary and derived demand prices for beef. Ultimately, as important as they are, production and marketing responses are not solely based on the wholesale or Yellow Sheet trade. Very short-term periods probably give more weight to the latter. Though alternative annual models were not tested here, economic theory and logic substantiate the empirical results that a retail rational lag structure composed of habits, real income, and market substitutes reverberate throughout the marketing system. The recent recession bears witness in that a reduction in retail beef prices was necessary to move existing production and stocks.

References

Arzac, E. R. and M. Wilkinson. "A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of its Policy Implications," *American Journal of Agricultural Economics*, 61(1979): 297–308.

Burt, O. R. "Estimation of Distributed Lags as Nonstochastic Difference Equations," Staff Paper No. 80-1, Department of Agricultural Economics and Economics, Montana State University, Bozeman, January 1980.

Crom, R. A. "A Dynamic Price-Output Model of the Beef and Pork Sectors," USDA Economic Research Service Tech. Bull. 1426, Washington, D.C. Government Printing Office, 1970.

Doane, Profit Marketing. St. Louis: Doane Agricultural Service, Inc. 1975.

Foote, R. J. Analytical Tools for Studying Demand and Price Structures. USDA Agr. Handbook No. 146, August 1958.

Franzmann, J. R. and R. L. Walker. "Trend Models of Feeder, Slaughter and Wholesale Beef Cattle Prices," *American Journal of Agricultural Economics*, 54(1972): 507–12.

Freebairn, J. W. and G. C. Rausser. "Effects of Changes in the Level of U.S. Beef Imports," *American Journal of Agricultural Economics*, 57(1975): 676–88.

Griliches, Z. "Distributed Lags: A Survey," *Econometrica*, 35(1967): 16–46.

Hanssens, D., M. and Lon-Mu Liu "Lag Specification in Rational Distributed Lag Structural Models," *Journal of Business and Economic Statistics*, (forthcoming) 1(1983).

Houck, J. P. "The Short Run Impact of Beef Imports on U.S. Meat Prices," *Australian Journal of Agricultural Economics*, 18(1974): 60–72.

Jorgenson, D. W. "Rational Distributed Lag Functions," *Econometrica*, 32(1966): 135–49.

Kulshreshtha, S. B. and A. G. Wilson. "An Open Econometric Model of the Canadian Beef Cattle Sector," *American Journal of Agricultural Economics*, 54(1972): 84–91.

Langemeir, L. and R. G. Thompson. "Demand, Supply and Price Relationships for the Beef Sector, Post World War II Period," *American Journal of Agricultural Economics*, 49(1967): 169–83.

Marsh, J. M. "Effects of Marketing Costs on Livestock and Meat Prices for Beef and Pork," Montana Agricultural Experiment Station, Bull. 697, Montana State University, Bozeman, May 1977.

Marsh, J. M. "A Rational, Distributed Lag Model of Quarterly Live Cattle Prices," *American Journal of Agricultural Economics,* 65 (1983), forthcoming.

Myers, L. H., J. Havlicek, Jr., and P. L. Henderson. "Short-Term Price Structure of the Hog-Pork Sector of the United States," Purdue University, Res. Bull. 855, February, 1970.

Nelson, G. and T. Spreen. "Monthly Steer and Heifer Supply," *American Journal of Agricultural Economics,* 60(1978): 117–25.

Pollak, R. A. "Endogenous Tastes in Demand and Welfare Analysis," *American Economic Review,* 68(1978): 374–85.

Reutlinger, S. "Short Run Beef Supply Response," *American Journal of Agricultural Economics,* 48(1966): 909–19.

Tomek, W. G. and K. L. Robinson. *Agricultural Product Prices,* Second Ed., Ithaca, New York, Cornell University Press, 1981.

Tryfos, P. "Canadian Supply Functions for Livestock and Meat," *American Journal of Agricultural Economics,* 56(1974): 107–13.

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

Walters, F. E., S. R. Moore, and H.-M. Neghassi. "Price and Demand Relationships for Retail Beef: 1947–1974," Colorado State University Experiment Station, Tech. Bull. 125, Fort Collins, May 1975.