TRANSMISSION OF WEEK-TO-WEEK CHANGES IN CHOICE BEEF PRICES BETWEEN FARM, CARCASS AND RETAIL LEVELS

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Introduction

Do retail beef prices respond promptly to changes in the farm price of live cattle? If not, why not? This issue has resulted in frequent controversy but little hard evidence has been assembled to establish the existence of short-term lags in price changes at different levels in the marketing process.

Interest in this question of lags was clearly evident during the public hearings of the Subcommittee on Domestic Marketing and Consumer Relations of the House Agriculture Committee held on November 19, 1974. On that occasion retailers, meat packers and spokesmen for the U. S. Department of Agriculture offered testimony concerning measures of beef price spreads and possible explanations for changes in reported values over time. Industry representatives made frequent reference to the omission of time lags in published USDA reports, holding that price spreads are overstated during periods of falling farm prices and understated during periods of rising prices. Several speakers noted that it is during the former periods that marketing firms come under scrutiny by both farm and consumer groups!

Long-term changes in price relationships are properly measured in terms of monthly or even quarterly values. However, week-to-week responses

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are often a source of anxiety on the part of farmer and consumer groups. This paper examines the relationships between weekly farm, carcass and retail values of Choice beef during a period following the lifting of retail price controls in mid-1973 when such anxiety was often expressed.

No attempt has been made to specify the structural equations which underly observed beef price behavior. Rather, emphasis is placed on evidence of "delay in adjustment to consistency" to borrow a phrase from Trierweiler and Hassler. The underlying hypothesis to be refuted is that no lags exist in the transmission of week-to-week price changes from farm to carcass level or from carcass to retail level.

The models are formulated in terms of prices rather than price spreads in the belief that implications for alternative spread configurations may be more readily derived in this way than from the choice of price spread as the dependent variable. However, this is largely a matter of taste.

Finally, it must be emphasized that more questions are raised than answered by these results. Important statistical problems remain, both in the area of model construction and in estimation procedures. The findings point to measurable differences in the transmission of price changes between farm, carcass and retail levels. These differences are consistent with popular views but the forces that bring about these results are left largely unexplained.

The Data Base

The study period selected extended from October, 1973 through September, 1975. Weekly estimates of net farm value, carcass value and retail value are those reported by the Meat Animals Program Area, CED, ERS.[1] These reports provide preliminary estimates of price changes before monthly Bureau of Labor Statistics reports on retail prices become available from which official monthly price spreads are calculated. As each weekly release emphasizes, "Weekly data fluctuate more than the monthly average and the weekly spreads are more likely to emphasize any discrepancy resulting from the use of prices for a point in time, rather than pricing the same piece of meat as it moves through the channel."

To understand the price changes which occurred in late 1973 it is important to recall that retail price controls, imposed in mid-1971, were not removed until September 1973 while farm prices were not subject to control. The price of live Choice steers fell slowly but steadily throughout the fall months of 1974. During that period the prices of inputs purchased by marketing firms rose at near-record rates as general inflation was experienced in every sector of the U.S. economy. Wage rates, fuel prices, utilities, rent, packaging materials and other marketing firm expenses rose steadily. As marketing firm costs increased, profit margins were dramatically reduced. Although retail beef prices declined, the decrease was not as rapid as the fall in live cattle prices, resulting in rising farm-retail price spreads and a decline in the farm share of the retail beef dollar.

Six month and two-year averages of the selected variables are provided in Table 1. The relationship of prices in the study period to earlier periods is shown in Figures 1 and 2 in terms of quarterly averages over the period 1966-1975. Beef prices were well below the two-year averages during the third six-month period and well above the average during the fourth period. Changes in spreads were much less dramatic, however.

Table 1. Mean values of prices, quantities and spreads for choice beef, October, 1973 through September 1975

Variables[a]	Units	Six-month averages[b] T_0	T_1	T_2	T_3	Two year average
Net farm value (F)	Cents/lb.	86.83	86.71	77.29	100.85	87.92
Carcass value (C)	Cents/lb.	98.28	98.00	88.63	114.13	99.76
Retail value (R)	Cents/lb.	140.02	137.67	132.14	151.20	140.25
Beef slaughter (QB)	Mil. lbs. per week	390.0	401.3	416.8	403.4	403.4
Pork slaughter (QP)	Mil. lbs. per week	244.5	246.0	236.7	196.6	231.0
Spreads:						
Farm-carcass (C-F)	Cents/lb.	11.45	11.29	11.34	13.28	11.84
Carcass-retail(R-C)	Cents/lb.	41.74	39.67	43.51	37.07	40.49
Farm-retail (R-F)	Cents/lb	53.19	50.96	54.85	50.35	52.33

[a]Variables are defined in Footnotes 1 and 2.

[b]Time periods: T_0 = October 6, 1973 - March 30, 1974; T_1 = April 6 - September 28, 1974; T_2 = October 5, 1974 - March 29, 1975; T_4 = April 5 - September 27, 1975.

Figure 1. Retail price, carcass value and net farm value, Choice grade beef, quarterly averages, 1966 - 1975

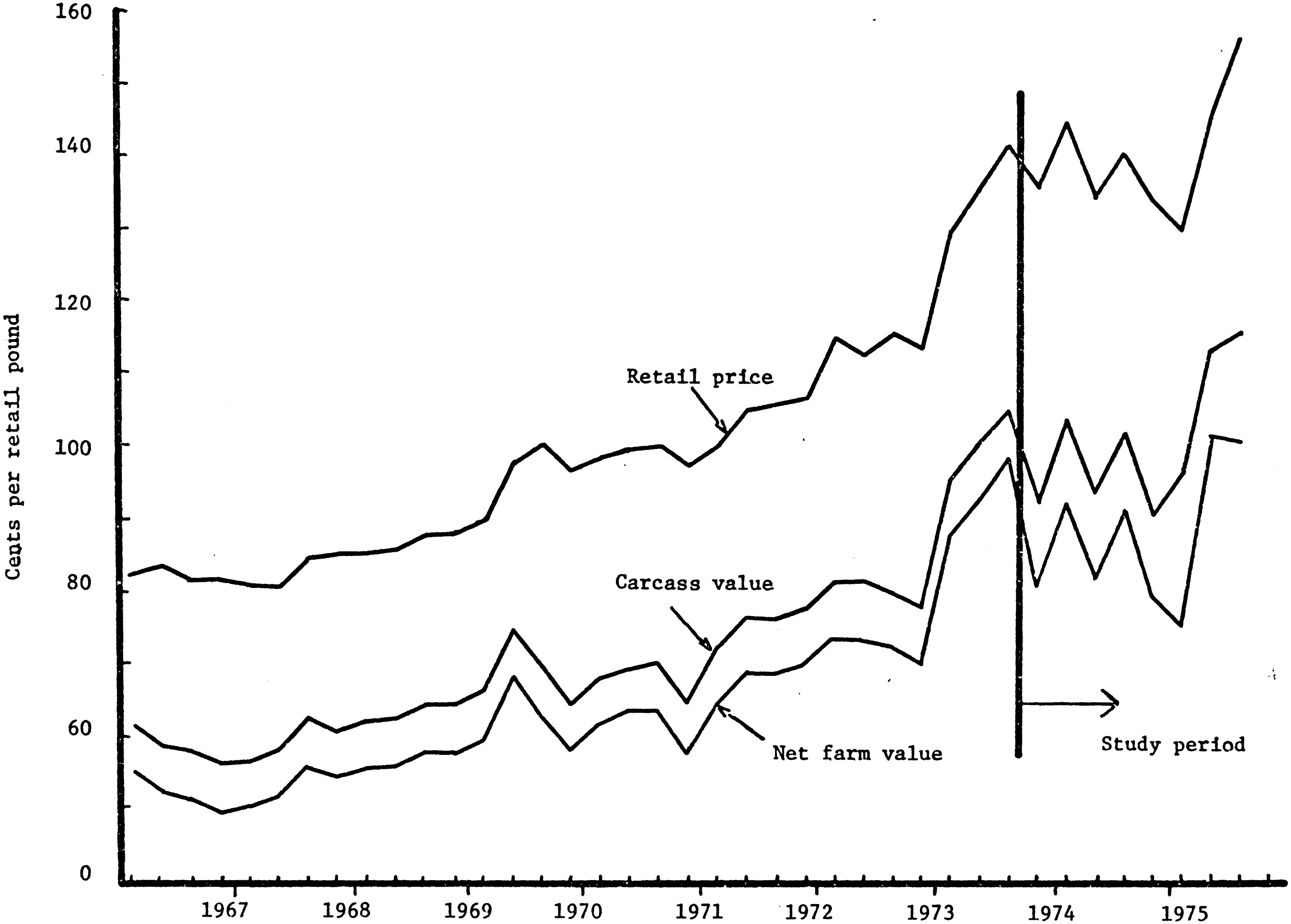
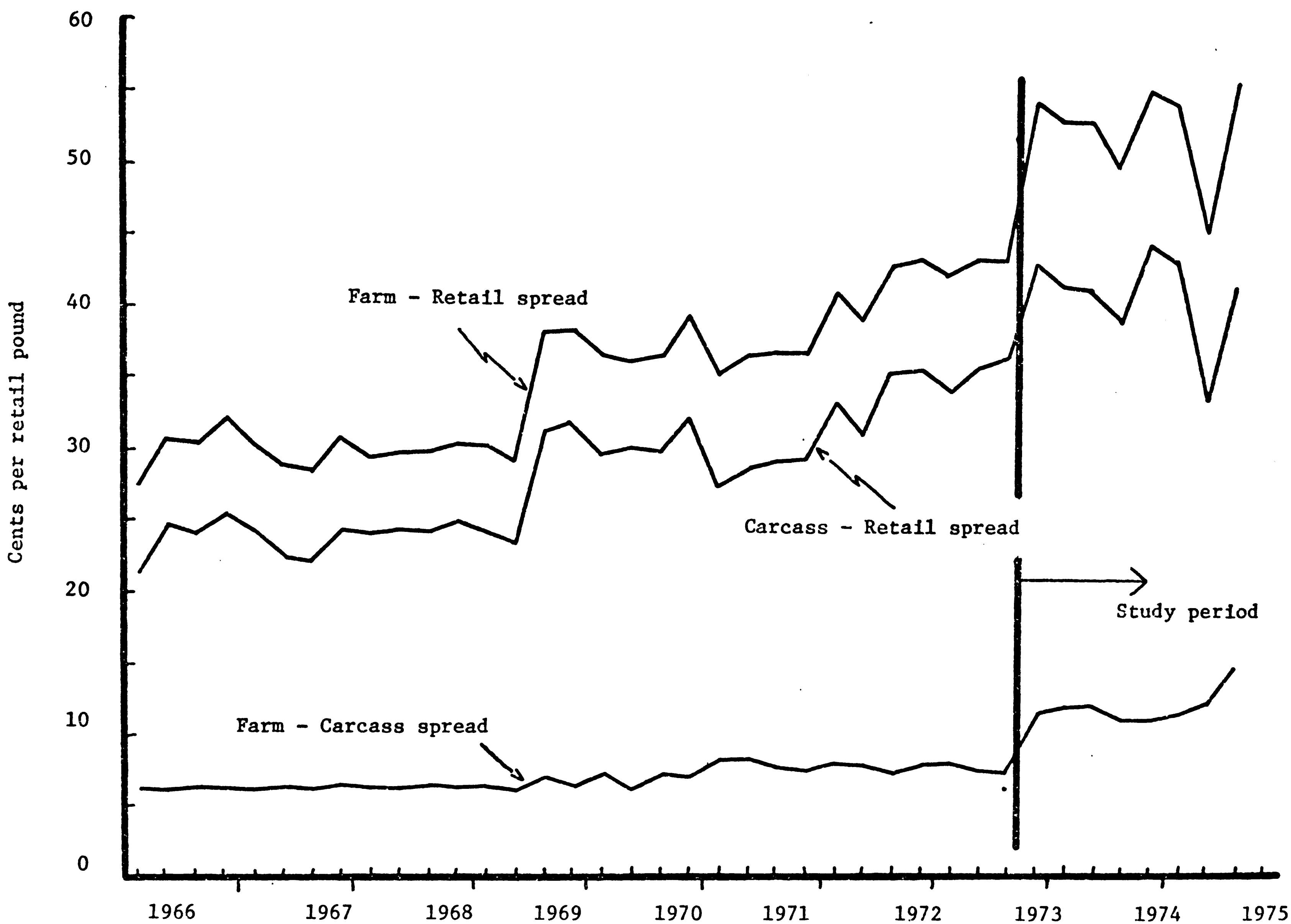


Figure 2. Price spreads for Choice grade beef, quarterly averages, 1966 - 1975



The quantities of beef and pork slaughtered weekly[2] were selected as independent variables for the purpose of examining the possible influence of volume on levels of prices and price spreads. To provide a rough measure of the impact of the upward drift in marketing costs six-month discrete time variables were introduced. A weekly marketing cost variable would have been preferable but such a series was not readily available.

Concurrent Price Relationships

The correlation between concurrent week net farm value and carcass value was quite high ($r^2 = .958$). A significant, if small, improvement was achieved by the addition of variables measuring the quantities of beef and pork slaughtered in the same week (see Appendix Table 1).[3] The estimated regression coefficients, associated standard errors and the usual .05 and .01 significance levels for equation CF1 are reproduced below:

$$\underset{}{C =} \underset{(4.11)}{7.96} + \underset{(.02454)}{1.03156F^{**}} + \underset{(.00793)}{.01782QB^{*}} - \underset{(.00870)}{.02635QP^{**}} \qquad R^2 = .962, \quad D\text{-}W = 1.58 \qquad (1)$$

The constant term is positive and significantly greater than zero at the .06 level, the farm value coefficient is slightly larger than but not significantly different from 1.0, the effect of quantity of beef slaughtered is positive and that of pork slaughtered is negative.

This relation may be expressed in the form of the farm-carcass spread (C-F) by subtracting F from each side. The spread increased slightly (but not significantly) as farm value increased and as the number of cattle slaughtered increased while decreasing with the number of hogs slaughtered. If larger supplies of beef reduce unit marketing costs through greater utilization of processing facilities it would be expected that carcass price would fall relative to farm price. On the other hand, if the slope of the demand curve at the farm level is steeper than that at the carcass level the spread would widen. It is interesting to observe that larger supplies of pork narrow the farm-carcass Choice beef spread.

Comparable results were obtained when net farm value was estimated as a function of carcass value as shown in the lower portion of Appendix Table 1. The regression coefficient for carcass value was significantly smaller than 1.0, thus supporting the earlier indication of a wider spread as carcass price rises. The constant term was not different from zero.

In comparison with the farm-carcass relation, the correlation between concurrent carcass value and retail value including the quantity variables was noticeably lower (.812 vs. .962) although direct comparison of the two is only suggestive. The effect on retail value of the quantity of beef and pork slaughter was no longer significant although the signs and magnitudes of the coefficients, shifters excluded, were similar to those reported for the farm-carcass relation (see Appendix Table 2). The simple regression of R on C shown below was as good as those equations in which the quantity variables were included.

$$R = \underset{(3.69)}{67.04^{**}} + \underset{(.03675)}{.73391^{**}}C \qquad R^2 = .80, \quad D\text{-}W = .62 \tag{2}$$

The relationship between farm value and retail value was found to be consistent with the farm-carcass findings reported earlier. Regression coefficients for quantities of beef and pork slaughter were statistically different from zero. Constraining the six-month shifters to be zero was appropriate as measured by a group F test of the difference in sum of squared residuals (see Appendix Table 3). The coefficients for equation RF2 are reproduced below:

$$R = 68.78^{**} + .75174^{**}F + .03508^{**}QB - .03796^{**}QP \quad R^2 = .804$$
$$(7.69) \quad (.04589) \quad (.01482) \quad (.01626) \quad D\text{-}W = .44 \qquad (3)$$

The conclusion that beef and pork slaughter quantities influence the farm-carcass spread but not the carcass-retail spread seems warranted by these results. A case might be made for an additive effect given the size of the quantity coefficients in (1) and (3). It is clear that there is a large fixed component in the carcass-retail spread that does not appear in the farm-carcass spread. As suggested by Gardner, this is what one would expect given the important non-beef inputs which are included in the carcass-retail spread.

There appear to be important differences between the relationship of farm to carcass values on the one hand and that of either farm or carcass values to retail price on the other. However, the low Durbin-Watson values for the carcass-retail and farm-retail relationships suggest that the simple linear model relating current values of the variables is not wholly satisfactory.

Lagged Price Relationships

Experimentation with first difference models indicated that the introduction of lagged response from farm to carcass level was of little value. However, either a one-week or two-week lag from carcass to retail level produced a substantial reduction in the sum of squared residuals.

This led to an investigation of the performance of polynomial distributed lag models.

The polynomial distributed lag model offers a more refined method of testing for the existence of lagged effects in beef price transmission than does the first difference model. Development of this model is attributed to Almon. Hall and Sutch provided a direct estimation technique. The two techniques are explained and the computational difference demonstrated by Cooper. Chen, Courtney and Schmitz have shown the superiority of the PDL model as compared with the less flexible geometrically declining lag model in studying production response. An interesting application of the PDL model to agricultural market price relationships has been provided by Ethridge.

A polynomial distributed lag model is characterized by (1) the functional form selected and (2) the number of periods (M) over which the lag is calculated. In this analysis both the quadratic and the cubic forms were used with the total number of periods varying from three to seven. The regressions of weekly carcass value on weekly farm value for M = 3 and M = 6 are summarized in Table 2. These are compared with regressions of weekly retail value on carcass value for the same lag lengths. In each equation the quantities of beef and pork slaughter are included. Positive signs were obtained for beef and negative signs for pork as was the case in the earlier analysis leading to the rejection of the hypothesis that either the farm-carcass or carcass-retail relation is independent of these flows.

Differences in lag structure are clearly identified by the polynomial distributed lag models. In the case of farm-carcass relationships shorter

Table 2 . Polynominal distributed lag relationships between carcass and farm value and between retail and carcass value, November 1973 through September 1975[a]

Item	Carcass value as function of net farm value		Retail value as function of carcass value	
	M = 3	M = 6	M = 3	M = 6
Constant term	8.59	11.85	59.50	57.39
Beef slaughter (QB)	.01750* (.00774)	.02048* (.00881)	.01701* (.00719)	.00403 (.00566)
Pork slaughter (QP)	-.02628** (.00848)	-.03395** (.00947)	-.02169** (.00807)	-.01459* (.00623)
Lag coefficients (k = length of lag)				
0	.8909	.6200	-.0926	.1220
1 week	.2167	.3491	.4272	.1623
2 week	-.0802	.1452	.4581	.1783
3 week	-	.0084	-	.1701
4 week	-	-.0614	-	.1376
5 week	-	-.0642	-	.0809
Sum of lags	1.03	1.00	.79	.85
Mean lag (weeks)	.05	.10	1.69	2.33
Test statistics:				
R^2	.965	.956	.956	.974
D-W	1.65	1.56	.74	.85
Sum of squared residuals	460	582	395	238

[a]Quadratic form estimates are reported here. Standard errors are shown in parentheses. Significance levels of .05 and .01 are indicated by * and ** respectively. N = 100 in each equation.

lag periods were associated with higher R^2. As M increased from 3 to 7 the sum of squared residuals rose. Coefficients were largest for the most recent time periods. The sum of the lags was approximately one with a mean lag of very close to zero. The current farm value weight was calculated to be .891 and that of the previous week was .217, both of which are quite close to the values obtained in the first difference analysis mentioned earlier.

In contrast to these findings, the statistical properties of the carcass-retail relationships improved as the length of lag in weeks increased from $M = 3$ to $M = 6$. In the three-period equation the term associated with the current week was negative while those for the second and third periods were roughly of equal size. As the number of weeks increased the value of R^2 rose and the weekly weights became of more nearly equal size. Although the seven-period model is not shown there was little difference between that and the six-week result. The mean lag for the latter model was 2.33 weeks with a lag weight sum of .85.

A number of additional comparisons were made which are not reported here in full. The cubic form of the polynomial distributed lag model was estimated for each of the relationships discussed above. There was a negligible improvement in the sum of squared residuals and changes in R^2 on the order of .001 where taken as evidence that the quadratic form was a satisfactory choice.

The suggestion that carcass price leads changes in the farm price was investigated. Results leave room for debate as to the appropriate choice of the direction of price transmission. The lag coefficients followed the farm-carcass form in that current lag coefficients were much larger than those for the second week (.80 vs .28 for example). Both models show the two prices are very closely interrelated.

In Conclusion

A general lack of understanding concerning the behavior of beef prices at different levels in the marketing system is emphasized in a number of recent studies by the U. S. Senate Select Committee on Nutrition and Human Needs, the U. S. House Subcommittee on Domestic Marketing and Consumer Relations and The Council on Wage and Price Stability. The Economic Research Service has repeatedly responded to requests for further explanation of price spread measures. The results of the analysis reported here may provide some further clarification.

The findings support the view that price transmission from farm to packer level occurs with a very short lag. In fact, it seems reasonable to regard price determination at farm and carcass levels as approximating an instantaneous process. That is clearly not the case with carcass-retail price behavior. The argument that measures of retail price response to changes in raw product costs should take into account appropriate lags is supported by the improvement in explanatory power of those models which include carcass value for as many as five previous weeks.

It was found that price spreads are positively associated with the quantity of beef moving through the system. Two reasons for this which come to mind are (1) when volume is high there may be less competition among packers to attract supplies and (2) marketing spreads widen to cover increasing marginal costs associated with larger plant output. The negative relationship between pork volume and beef spreads may well reflect the incentive to make beef more attractive to consumers in the face of larger supplies of the competing product.

FOOTNOTES

[1]These price series are derived independently and represent the value of quantities equivalent to one pound of Choice beef sold in retail stores. The net farm value (F) is calculated from U. S. Choice steer prices on seven midwest markets and in California adjusted for farmer marketing costs and byproduct values. The carcass value (C) is calculated from Choice steer carcass prices in Chicago and three West Coast cities. The retail value of Choice beef (R) represents a volume-weighted average of 29 cuts priced weekly in 40 retail chain stores adjusted to BLS monthly prices which include all types of retail outlets in 56 cities throughout the country.

[2]The quantity of beef (QB) and the quantity of pork (QP) are slaughter weights reported by packers operating under federal inspection published in Livestock and Meat Statistics, Agricultural Marketing Service, USDA.

[3]The increase in sum of squared residuals associated with the restriction that the two quantity variables each equal zero was significant as measured using the mean square error F test. This test was used throughout for purposes of comparison.

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MATHEMATICAL APPENDIX*

*This represents a somewhat expanded discussion of that provided by Ethridge (1975).

A Polynomial Distributed Lag Model

Suppose that the relation between X and Y can be represented by a distributed lag function of the form

$$(1) \quad Y_t = f\ (X_t, X_{t-1}, X_{t-2}, \ldots, X_{t-k}) \ .$$

A general linear expression for (1) is:

$$(2) \quad Y_t = \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_{m-1}\ X_{t-(m-1)}$$

$$= \sum_{k=0}^{m-1} \beta_k\ X_{t-k}$$

where the lag associated with observed values of the independent variable is identified by $k = 0, 1, \ldots, m - 1$ and m = total number of time periods considered including t.

If the coefficients are restricted to lie on a polynomial of degree n, then each parameter of equation 2 may be written as:

$$(3) \quad \beta_k = a_0 + a_1 k + a_2 k^2 + \ldots + a_n k^n$$

$$= \sum_{j=0}^{n} a_j k^j$$

and equation (2) may be written as:

$$(4) \quad Y_t = \sum_{k=0}^{m-1} \left(\sum_{j=0}^{n} a_j k^j \right) X_{t-k}.$$

It is assumed that values of β are zero for time period m and for all previous periods. Using equation (3) we may write, for $k = m$,

$$(5) \quad \beta_m = a_0 + a_1 m + a_2 m^2 + \ldots + a_n m^n = 0.$$

Solving (5) for a_0 and substituting in (3) we find

$$(6)\quad \beta_k = \sum_{j=1}^{n} a_j \, (k^j - m^j)$$

and rewrite (2) as:

$$(7)\quad Y_t = \sum_{k=0}^{m-1} \left(\sum_{j=1}^{n} a_j \, (k^j - m^j) \right) X_{t-k} \, .$$

We now define n new variables, Z_{tj}, as weighted sums of the independent variable which depend upon the selected value of m:

$$(8)\quad Z_{tj} = \sum_{k=0}^{m-1} (k^j - m^j) \, X_{t-k}, \quad j = 1, 2, \ldots, n,$$

and rewrite (7) as:

$$(9)\quad Y_t = \sum_{j=1}^{n} a_j \, Z_{jt}$$

Selecting the second degree polynomial form, n = 2, relation (9) becomes

$$(10)\quad Y_t = a_1 \, Z_{1t} + a_2 \, Z_{2t} \, .$$

The coefficients a_1 and a_2 may now be estimated by regressing Y on Z_1 and Z_2 and the lag coefficients, β_k, calculated from equation (6). For example, letting m = 3 we find:

$$\beta_0 = -3a_1 - 9a_2$$

$$\beta_1 = -2a_1 - 8a_2$$

and $\beta_2 = - a_1 - 5a_2$

with $Y_t = \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2}$

Appendix Table 1. Factors influencing carcass value and net farm value of choice beef, October 1973 through September 1975[a]

Equation number	Constant	Net farm value	Carcass value	Quantities slaughtered: Beef	Quantities slaughtered: Pork	Sum of squared residuals	R^2	D-W
Carcass value dependent:								
CF1	7.96 (4.11)	1.03156** (.02454)	-	.01782* (.00793)	-.02635** (.00870)	512.4	.962	1.58
CF2	12.95 (3.53)	1.03528** (.02498)	-	-	-.01827* (.00808)	538.3	.960	1.56
CF3	2.72 (3.88)	1.06742** (.02236)	-	.00790 (.00751)	-	559.5	.959	1.49
CF4	6.25 (1.95)	1.06354** (.02206)	-	-	-	565.6	.958	1.47
Net farm value dependent:								
FC1	-2.00 (3.85)	-	.92543** (.02133)	-.01495* (.00727)	.01521 (.00819)	409.3	.964	1.67
FC2	1.26 (3.47)	-	.90464** (.01838)	-.00918 (.00666)	-	424.0	.963	1.59
FC3	-2.81 (1.84)	-	.90830** (.01828)	-	-	432.3	.962	1.55

[a]Standard errors are shown in parentheses. N = 104. Critical values of t are 1.98 (.05) and 2.63 (.01) identified by * and ** respectively.

Appendix Table 2. Factors influencing retail value of choice beef, including carcass value, October 1973 through September 1975[a]

Equation number	Constant	Carcass value	Quantity slaughtered: Beef	Quantity slaughtered: Pork	Six-month shifters: T_1	Six-month shifters: T_2	Six-month shifters: T_3	Sum of squared residuals	R^2	D-W
Arithmetic form:										
RC1	68.19	.68130**	-.03318	-.03328	-2.417*	-2.385	-1.591	1714.4	.812	.66
	(8.88)	(.06346)	(.01759)	(.02138)	(1.175)	(1.463)	(1.776)			
RC2	65.64	.70829**	.02292	-.02291	-	-	-	1800.4	.803	.64
	(7.85)	(.04339)	(.01493)	(.01677)						
RC3	67.04	.73391**	-	-	-	-	-	1853.8	.800	.62
	(3.69)	(.03675)								
Logarithmic form:										
lnRC1	2.4754	.48148**	.10530*	-.06738*	-.01823*	-.01761	-.01484	.083097	.832	.66
	(.3141)	(.04513)	(.04801)	(.03305)	(.00819)	(.01028)	(.01243)			
lnRC2	2.4852	.49629**	.07096	-.04614	-	-	-	.087967	.822	.63
	(.2811)	(.03078)	(.04063)	(.02563)						
lnRC3	2.5463	.52105**	-	-	-	-	-	.091767	.814	.60
	(.1215)	(.02643)								

[a]Standard errors are shown in parentheses. N = 104. Critical values of t are 1.98 (.05) and 2.63 (.01) identified by * and ** respectively.

Appendix Table 3. Factors influencing retail value of choice beef, including net farm value, October 1973 through September 1975[a]

Equation number	Constant	Net farm value	Quantity slaughtered		Six-month shifters			Sum of squared residuals	R^2	D-W
			Beef	Pork	T_1	T_2	T_3			
Arithmetic form:										
RF1	70.43 (8.63)	.73205** (.06742)	.04594** (.01742)	-.04904* (.02092)	-2.61* (1.17)	-2.41 (1.45)	-1.96 (1.78)	1693.5	.814	.48
RF2	68.78 (7.69)	.75174** (.04589)	.03508* (.01482)	-.03796* (.01626)	-	-	-	1791.5	.804	.44
RF3	70.52 (3.61)	.79319** (.04077)	-	-	-	-	-	1931.7	.788	.39
Logarithmic form:										
lnRF1	2.5612 (.3030)	.45852** (.04201)	.13989** (.04723)	-.09109** (.03216)	-.01909* (.00809)	-.01673 (.01016)	-.01759 (.01235)	.081044	.836	.51
lnRF2	2.6158 (.2729)	.46398** (.02840)	.10411* (.04002)	-.06859** (.02469)	-	-	-	.086294	.825	.45
lnRF3	2.7288 (.1147)	.49502** (.02566)	-	-	-	-	-	.094986	.808	.39

[a]Standard errors are shown in parentheses. N = 104. Critical values of t are 1.98 (.05) and 2.63 (.01) identified by * and ** respectively.