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Before the late 1970's farm-retail price spreads for beef and pork were fairly stable and predictable. Since around 1978-1980, price spreads have (a) increased, (b) become more volatile, and (c) changed seasonal patterns. The reasons for the changes are not well understood. Our inability to account for them has made it difficult for outlook workers to make reliable price predictions. This study investigates some possible explanations of the changes in the margins. Finding explanations may pave the way for more reliable price forecasts.

Hypotheses

Recent studies of meat margins have derived their econometric models from theory of a single-product firm. See Gardner (1975), Heien (1980), Lamm and Westcott (1981), and Ikerd (1984). We derive two of our hypothesized explanations from Holdren's (1960) theory of a multiproduct firm because many firms that handle beef or pork handle both.

Let p_i and q_i $(i = 1, 2)$ represent price charged and quantity sold of product i and let $C(q_1, q_2)$ be total cost. A two-product firm's profit is

$$\pi = p_1 q_1 + p_2 q_2 - C(q_1, q_2)$$

Manipulating the first order condition for $\partial\pi/\partial p_1 = 0$ yields

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$$(1)\quad p_1 - \partial C/\partial q_1 = -\,[q_1 + (p_2 - \partial C/\partial q_2)(\partial q_2/\partial p_1)]/(\partial q_1/\partial p_1)$$

There is a similar expression for product two. According to (1) each product's margin of price over marginal cost is related to the other product's margin. We hypothesize that beef and pork margins are interrelated and hence include a beef-margin variable in the pork-margin equation, and vice versa. Ladd and Karg (1973) found that farm-wholesale pork margin affected farm-wholesale beef margin and that wholesale-retail pork margin affected wholesale-retail beef margin, and vice versa.

Our second hypothesis comes from manipulation of equation (1). The partial derivative of the margin on product one with respect to the own-price slope of the demand equation can be written

$$(2)\quad \frac{\partial(p_1 - \partial C/\partial q_1)}{\partial(\partial q_1/\partial p_1)} = [q_1 + (p_2 - \partial C/\partial q_2)\,\frac{\partial q_2}{\partial p_1}] \;/\; (\frac{\partial q_1}{\partial p_1})^2$$

$$= -(p_1 - \partial C/\partial q_1) \;/\; (\partial q_1/\partial p_1)$$

If $\partial q_1/\partial p_1 < 0$ and $(p_1 - \partial C/\partial q_1) > 0$, expression (2) is positive. As $\partial q_1/\partial p_1$ increases (becomes closer to zero), the profit margin grows. In addition,

$$(3)\quad \partial(p_1 - \partial C/\partial q_1)/\partial(\partial q_2/\partial p_1) = -\,(p_2 - \partial C/\partial q_2)/(\partial q_1/\partial p_1)$$

If $(p_2 - \partial C/\partial q_2) > 0$, an increase in $\partial q_2/\partial p_1$ increases the margin on product one. We hypothesize that slopes of the retail demand functions for beef and pork have changed, and that these changes have generated changes in behavior of beef and pork margins.

Our third hypothesis is an extension of our second, and is one that Ikerd (1984) has investigated: there have been changes in other coefficients in the retail demand equations and changes in coefficients in the margin equations.

Econometric Model

We have studied two different models. Both were estimated by use of monthly data. This paper reports results for Model I--the simpler model. Variables are defined in Table 1.

The six equations in Model I are

$$(4)\quad DP_{Bt} = b_{10} + b_{11}Q_{Bt} + b_{12}Q_{Pt} + b_{13}DY_t + \Sigma_i \delta_{1i}S_{it} + \varepsilon_{1t}$$

$$(5)\quad DP_{Pt} = b_{20} + b_{21}Q_{Bt} + b_{22}Q_{Pt} + b_{23}DY_t + \Sigma \delta_{2i}S_{it} + \varepsilon_{2t}$$

$$(6)\quad M_{Bt} = a_{11}M_{Pt} + a_{12}VF_{Bt} + c_{11}IC_t + c_{10} + \Sigma \delta_{3i}S_{it} + \varepsilon_{3t}$$

$$(7)\quad M_{Pt} = a_{21}M_{Bt} + a_{22}VF_{Pt} + c_{21}IC_t + c_{20} + \Sigma \delta_{4i}S_{it} + \varepsilon_{4t}$$

$$(8)\quad VF_{Bt} = P_{Bt} - M_{Bt}$$

$$(9)\quad VF_{Pt} = P_{Pt} - M_{Pt}$$

The M_{Jt} are not the same as Holdren's margin: $p_i - \partial C/\partial q_i$. We assume that the difference between M_{Jt} and Holdren's margin is related to the same variables that affect M_{Jt}.

The system is block-recursive. Equations (4) and (5) were estimated by single-equations methods. Equations (6) and (7) were

Table 1. Definitions of Monthly Variables

Variable	Definition and classification
DP_{Jt}	Deflated retail price of product J in period t; J = B for beef, J = P for pork in \$/100 lb. retail, 1967 dollars; endogenous
Q_{Jt}	Per capita retail quantity of product J, period t; exogenous
DY_t	Deflated per capita disposable personal income, month t; 1967 dollars; exogenous
S_{it}	Value of i-th seasonal variable, period t; exogenous S_{2t} = 1 in February = 0 otherwise . . . S_{12t} = 1 in December = 0 otherwise
M_{Jt}	Farm-retail margin on product J in \$/100 lbs. retail, period t; endogenous
VF_{Jt}	Farm value in \$/100 lbs. retail; endogenous
IC_t	Index of cost; Weighted average of meat packing wage rate, food store wage rate, and producer price index of intermediate goods, each series converted to 1967-100; exogenous
P_{Jt}	Nominal retail price of product J, period t in \$/100 lbs. retail; endogenous

estimated by simultaneous equations methods.

In Model II each farm-retail margin is disaggregated into a farm-wholesale and a wholesale-retail margin.

We used monthly data for January 1968 through June 1984, and treated 1968 through 1977 as Sample Period 1, and treated 1978 et.seq. as Sample Period 2. This division was chosen to coincide with the observed changes in the level, volatility, and seasonal pattern of the beef and pork marketing margins that occurred between 1977 and 1978. Sources of structural change for demands and marketing margins in the 1970's may include the increased health concern about red meat consumption, the changes in the beef grading standards, and the move to boxed beef. We felt that demand and margin coefficients may differ between the two sample periods due to the influence of these and other changes. We tested the hypothesis that coefficients had the same values in Period 2 as in Period 1.

Tests of Hypotheses of Equality of Coefficients

To test the equality of coefficients in Periods 1 and 2 we used the Chow test--an F ratio. A test of equality of coefficients is a test of a restriction. Dhrymes et al. (1972) compare various tests of restrictions in single equations and in systems of equations. Most presentations of tests of equality assume errors are independent and homoscedastic. We encountered autocorrelated errors and heteroscedasticity and had to correct for these before computing tests for equality.

Decomposition of Mean Differences

To obtain additional insight into causes of changes in margins we decomposed the mean monthly differences of the endogenous variables.

Use January data to illustrate the procedure. Pick out all the January observations used to estimate equation (4), or equation (5), for Period s, and express the relationship as

$$(10)\quad DP_{Jts} = \sum_i b_{is} X_{its} + \varepsilon_{its}$$

X_{its} is the value of explanatory variable i in the t-th January in sample period s (s = 1, 2). Let $\bar{X}_{is}$ and $\bar{DP}_{Js}$ denote the mean values of X_{its} and of estimated mean of DP_{Jts}. Then $\bar{DP}_{Js} = \sum_i b_{is} \bar{X}_{is}$ and the mean difference can be decomposed as

$$(11)\quad \bar{DP}_{J2} - \bar{DP}_{J1} = \sum_i b_{i1}(\bar{X}_{i2} - \bar{X}_{i1}) + \sum_i \bar{X}_{i1}(b_{i2} - b_{i1})$$

$$+ \sum_i (\bar{X}_{i2} - \bar{X}_{i1})(b_{i2} - b_{i1})$$

The first term on the right-hand side of (11) equals the change that occurred in January means due to changes in mean values of exogenous variables, with coefficients constant. The second equals the change in mean values due to changes in coefficients, with exogenous variables constant at their initial levels. The third term measures change due to interactions between changes in exogenous variables and changes in coefficients. This procedure was applied to (4) and (5) to decompose the mean differences in deflated retail prices in each calendar month.

Equations (10) and (11) refer to deflated retail prices. Equations (6) through (9) contain nominal prices. To determine effects upon margins of changes in demand, we need to use nominal retail prices.

Estimated nominal retail prices can be obtained from (10) by multiplying by the consumer price index (and dropping the residual).

$$P_{Jts} = \Sigma_i b_{is} (X_{its} CPI_{ts}) = \Sigma_i b_{is} W_{its}$$

or, at the mean,

$$(12) \quad \bar{P}_{Js} = \Sigma_i b_{is} \bar{W}_{is}$$

$\bar{P}_{J2} - \bar{P}_{J1}$ can be decomposed by an expression like (11) with $\bar{W}_{is}$ replacing $\bar{X}_{is}$.

The derivation applied to (10) to obtain (11) can also be applied to the reduced form of equations (6) through (9). Use

$$M_{ts} = \Sigma_i \pi_{is} Z_{its} + \Sigma_i f_{Js} P_{Jts}$$

to represent one of the reduced form equations for January observations in Period s. The January mean is

$$\bar{M}_s = \Sigma_i \pi_{is} \bar{Z}_{is} + \Sigma_J f_{Js} \bar{P}_{Js}$$

One way to investigate the hypothesis derived from Holdren's model that margins are affected by changes in slopes of the demand functions is to ask, "What would margins have been in Period 2 if the only differences that had occurred between Periods 1 and 2 were changes in these coefficients?"

The effect of changes in demand upon margins and farm values can be written

$$(13) \quad M_2^* - \bar{M}_1 = \Sigma_J f_{J1} (\bar{P}_{J2} - \bar{P}_{J1})$$

This expression shows how Period 2 margins and farm values would have differed from those of Period 1 if coefficients in equations (6) and (7) had remained constant and if $\bar{Z}_{i2} = \bar{Z}_{i1}$. The results of decomposing $\bar{P}_{J2} - \bar{P}_{J1}$ can be substituted into (13) to decompose the effects upon margins of changes in demand.

Empirical Results

Estimated Equations

Estimated demand and margin equations are presented in Table 2. (To save space, seasonal coefficients are not shown.) Variable PR73=1 from March through September of 1973, when price ceilings were in effect, and equals zero in other months. The demand equations for Period 1 had to be adjusted for autocorrelation and for heteroscedasticity. Before adjusting for heteroscedasticity, residual variance in each demand equation was about three times as large after December 1972 as before. Residual variance in the beef demand equation was also larger in Period 2 than in Period 1. F statistics for tests of constancy of all coefficients are also included in Table 2. The null hypothesis of constancy of coefficients was rejected at the 1 percent level in both demand equations. The null hypothesis of no change in seasonal coefficients was not rejected for either equation, however.

The direction of movement in the coefficients of both demand equations is the same. The own-quantity slopes rose (became less negative) while the cross-quantity slopes fell. The income coefficients rose substantially while the intercepts fell substantially for both

Table 2. Estimated Equations, 1968 Through 1977, and 1978 Through June 1984[a/]

	Demand Equations					
	Inter.	QB	QP	Income	PR73	F
Beef demands						
Period 1	47.29	-0.84	0.72	15.26	3.99	
	(4.64)	(-2.57)	(1.42)	(4.57)	(2.00)	
Period 2	0.01	-0.43	-0.10	25.70		7.24**
	(0.58)	(-0.92)	(0.15)	(11.44)		
Pork demands						
Period 1	38.96	0.98	-2.04	9.56	4.45	
	(3.65)	(2.81)	(-3.75)	(2.73)	(1.88)	
Period 2	0.14	0.21	-0.67	20.78		4.79**
	(1.95)	(0.84)	(-1.84)	(19.93)		

	Margin Equations				
	Inter.	MP	FVB	IC	
Beef margins					
Period 1,2	-4.43	0.21	0.06	0.26	
	(-2.01)	(2.35)	(1.29)	(7.48)	
	Inter.	MB	FVP	IC	
Pork margins					
Period 1	0.19	0.0	0.13	0.26	
	(0.05)		(2.64)	(8.39)	
Period 2	0.19	0.40	0.13	0.12	5.84*
	(0.05)	(2.43)	(2.64)	(2.07)	

[a/] Coefficient on top line, t ratio in parentheses, 1%, 5% and 10% significance levels are 2.60, 1.97, and 1.64.

* Significant at $\alpha = .05$.

** Significant at $\alpha = .01$.

commodities. Most coefficients in the Period 1 demand equations are significant. The Period 2 demand equations, however, are imprecisely determined. This imprecision may affect the analysis of structural change.

Margin equations were estimated by autoregressive two-stage-least squares. After adjusting margin equations for autocorrelation we found residual variances to be 75 percent larger in Period 2 than in Period 1. This implies that margins have become more difficult to forecast because the random components of their variances have become larger.

The seasonal coefficients as a group were nonsignificant in both periods in the beef margin equation. There is, however, a seasonal pattern in beef margins that is generated by seasonal variations in pork margin and in farm value of beef. The hypothesis of no changes in the coefficients in the pork margin equation was rejected at the 5 percent level. Seasonal coefficients did not exhibit significant change, however, and the intercepts and coefficients of FVP_t remained the same in the two periods. The significant F ratio is due to changes in coefficients of MB_t and IC_t. The estimated coefficient of MB_t was small and negative for the first period and so it was restricted to be zero in the equation in Table 2.

Decomposition of Mean Monthly Differences

Between Periods 1 and 2, nominal retail beef and pork prices rose by \$1.02 and \$0.57 per pound, respectively, on average. Results of decomposing these mean differences are easily summarized.

A. Effects of changes in coefficients and in monthly values of explanatory variables were nearly the same in every calendar month.

B. Given constant independent variables, changes in intercepts and in cross-quantity slopes by themselves reduced retail prices. Changes in own-quantity slopes and in income coefficients raised prices. The overall effects of changes in coefficients were to reduce nominal mean retail prices of beef and pork by 20¢ and 5¢ per pound.

C. The change in mean Q_P reduced mean retail beef and pork prices. Changes in other means increased retail prices. Overall effect of changes in means of independent variables, with constant coefficients, was to increase nominal retail beef and pork prices by 63¢ and 36¢ per pound.

D. Interactions between changes in coefficients and changes in variables increased nominal beef and pork prices by 49¢ and 51¢ per pound.

Equation (11) was also applied to the reduced form of equations (13) to decompose changes in margins between Periods 1 and 2. The major components of the change for both beef and pork margins were the changes in the means of the cost index and retail prices. Out of the total increase in the average monthly mean beef margin of $45.33 per cwt., $38.63 was due to the change in the average monthly mean of the cost index. Another $6.70 was due to the change in the average retail price of beef and pork. The remainder was due to the coefficient changes in the margin equation for pork and the interaction of coefficient and mean changes in the margin variables.

The $36.52 per cwt. increase in the average monthly mean pork margin between period one and period two was broken into the same set of components. The change in the average monthly mean of the cost index

accounts for \$30.13 while the change in the average monthly mean retail price accounts for \$6.54 of the total change. The sum of the other components, some of which are negative, make up the remainder of the pork margin change.

Results in the two preceding paragraphs were obtained by treating changes in P_B and P_P as exogenous. We also determined effects on margins and farm values of changes in coefficients in demand equations, changes in means of variables in demand equations, and their interaction. This was done according to equation (13). Summary statistics of changes due to these components are presented in Tables 3, 4, and 5. In reading these tables, keep in mind that the main source of increase in margins was the increase in the cost index and that average values of VF_B and FV_P rose by \$57.03 and \$20.06 per cwt. between Periods 1 and 2.

Table 3 answers 'what if' questions concerning margin and farm value changes due to demand coefficient changes. If the only change between Period one and Period two had been the increase in the two own-quantity slopes of the demands, the beef margin would have risen by \$0.51 per cwt. The pork margin would have risen by \$1.13 per cwt. Likewise, if the only changes between the periods had been in the demand coefficients, the beef margin would have fallen by \$1.18 and the pork margin would have fallen by \$0.62 per cwt. from their period one means. One striking result is the relatively large effect on margins and farm values from the change in the income coefficient. The fall in the intercept has more than offset the change due to the change in the income coefficient.

Table 4 answers 'what if' questions concerning margin and farm value changes due to mean changes in demand variables. If the only

Table 5. The Mean of the Monthly Mean Margin and Farm Value Changes Due to the Interaction of Changing Coefficients and Means of Demand Variables; in $/cwt

	Own-quantity	Cross-quantity	Income	All variables
Beef Margin Changes:				
Mean of the monthly changes	0.17	0.11	3.48	3.76
Variance of the monthly changes	0.00	0.00	0.01	0.01
Range of the monthly changes	0.06	0.05	0.24	0.25
Pork Margin Changes:				
Mean of the monthly changes	1.11	-0.84	5.61	5.89
Variance of the monthly changes	0.01	0.00	0.01	0.02
Range of the monthly changes	0.19	0.18	0.36	0.45
Beef Farm Value Changes:				
Mean of the monthly changes	-1.28	5.22	41.69	45.63
Variance of the monthly changes	0.01	0.15	0.83	1.12
Range of the monthly changes	0.26	1.10	2.86	3.21
Pork Farm Value Changes:				
Mean of the monthly changes	8.54	-6.40	42.91	45.05
Variance of the monthly changes	0.36	0.16	0.83	1.17
Range of the monthly changes	2.38	1.39	2.79	3.43

although we could not identify a statistically significant change--indications are that there is no one major source of that change.

Conclusions

Our ability to use the historical record to predict prices and margins has suffered because of two different sets of structural changes. (1) Coefficients in the structural equations have changes. (2) Variances of error terms in the structural equations have become larger.

Our first conclusion supports Ikerd's (1984) finding of changes in coefficients. But we place the change earlier than he did: 1978 rather than 1980. To some extent we may compensate for this change by using only recent data to estimate our forecasting equations.

Trying to compensate for the second structural change, however, is difficult. It is like trying to develop a system for forecasting the next roll of the dice.

Results in Tables 3 and 5 show that about 10 percent of the increase in mean margins between Periods 1 and 2 can be attributed to changes in coefficients in the demand equations. Some individual coefficient's changes had relatively large effects, but were offset by other coefficient's changes.

The major cause of increases in margins between Periods 1 and 2 was the increase in the cost index.

This paper is a progress report, not a final report. From a study of Model II, which contains farm-wholesale and wholesale-retail margins, we hope to obtain more complete and useful information on causes of changes in margin behavior.

References

Dhrymes, Phoebus J., E. P. Howrey, S. H. Hymans, J. Kmenta, E. E. Leamer, R. E. Quandt, J. B. Ramsey, H. T. Shapiro and V. Zarnowitz. "Criteria for Evaluation of Econometric Models." Annals Econ. and Soc. Measurement 1 (1972):291-324.

Gardner, Bruce L. "The Farm-Retail Price Spread in a Competitive Food Industry." Amer. J. Agric. Econ. 57 (1975):399-409.

Heien, Dale M. "Markup Pricing in a Dynamic Model of the Food Industry." Amer. J. Agric. Econ. 62 (1980):10-18.

Holdren, Bob R. The Structure of a Retail Market and the Market Behavior of Retail Units. Ames, Iowa State Univ. Press. 1968.

Ikerd, John E. "Forecasting Spreads Between Retail Beef and Live Cattle Prices: A Model for Routine Use by Market Analysis." Pp. 301-318 in NCR-134 Conference on Applied Commodity Price Analysis and Forecasting. Iowa State Univ. 1984.

Ladd, George W. and Georg Karg. Econometric and Programming Analyses of the Beef-Pork Marketing Sector. Iowa Agric. and Home Econ. Exp. Sta. Res. Bul. 577. 1973.

Lamm, R. McFall, Jr. and Paul C. Westcott. "The Effects of Changing Input Costs on Food Prices." Amer. J. Agric. Econ. 63 (1981):187-196.