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PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE (NE-165)

AGRICULTURAL PRICE SPREADS AND MARKET PERFORMANCE

by

Azzeddine Azzam, Emilio Pagoulatos, and John Schroeter*

WP-9 November 1988

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I. Introduction

Agricultural price spreads are commonly used as measures of the performance of food processing industries. These spreads, or "marketing margins," are defined as the difference between the retail or wholesale prices of a specific food and the farm price of the equivalent quantity of agricultural product.[1] Producer groups, consumer advocates, and policymakers all appeal to margin figures in promoting their views of industry performance; and a substantial technical literature has developed on the subject.[2] Most of these studies have examined the relationship between farm and retail or wholesale food prices under the assumption of perfect competition in the processing industry. While this approach may provide useful first approximations to margin behavior, it does not address the fundamental concern regarding agricultural price margins; namely, the possibility that "large" or growing margins may be due, in part, to abuses of market power at various stages within the processing industry.

This paper builds on recent theoretical and empirical contributions to industrial organization to provide a model of price spreads in noncompetitive food industries. Using this model, an empirical technique is developed for decomposing observed margins into components reflecting the marginal costs of the processing industry and oligopoly/oligopsony price distortions. This paper also reports the results of an application of the procedure to a time series of spreads between wholesale pork prices and farm prices of market hogs. Briefly, the findings suggest that although the hog packing industry has become somewhat more concentrated in the past decade, hog/pork margin decompositions reveal far less evidence of noncompetitive behavior in the 1980s than they did in the 1970s.

II. Theoretical Model

The model assumes that the food industry processes a raw agricultural input into a single homogeneous food product. Each firm utilizes a production technology characterized by a fixed proportional relationship between the agricultural input and the industry's output. With appropriately chosen dimensions, the quantities of the agricultural input and output can then be represented by the same variable for the j^{th} firm (Q^j), and by the same variable for the entire industry consisting of N firms ($Q = \Sigma_{j=1}^{N} Q^j$).

Conversion of the farm product to food output requires the use of nonagricultural inputs that are purchased in competitive factor markets and that can be employed in variable proportions. Denote the quantity of the i^{th} nonagricultural input employed by the j^{th} firm by x_i^j and let the processing cost function of the j^{th} firm be denoted $C^j(Q^j, \mathbf{w})$, where $\mathbf{w}$ is a vector of the w_i's, the prices of the nonagricultural factors. The industry faces a supply function for the farm product

$$Q = G(p_h, Z_1) \tag{1}$$

and a demand function for its output

$$Q = H(p_p, Z_2) \tag{2}$$

where p_h and p_p are the prices of the farm product and the processed food item, respectively, and Z_1 and Z_2 are vectors of exogenous variables.

Profit maximization requires that the j^{th} food processing firm choose Q^j to maximize

$$p_p Q^j - p_h Q^j - C^j(Q^j, \mathbf{w})$$

subject to the restrictions on prices and quantities implicit in equations (1) and (2), and choose quantities of the nonagricultural factors to minimize processing costs for the optimal output level. Since the prices of the nonagricultural inputs are parametric, their cost minimizing employment levels satisfy Shephard's lemma:

$$x_i^j = \partial C^j(Q^j, \mathbf{w})/\partial w_i \quad \text{for all i.} \tag{3}$$

The first order necessary condition for optimal output is

$$p_p(1 + \theta^j/\mu) - p_h(1 + \theta^j/\varepsilon) - \partial C^j/\partial Q^j = 0 \tag{4}$$

where $\mu = (\partial H/\partial p_p)p_p/Q$, the elasticity of industry demand;

$\varepsilon = (\partial G/\partial p_h)p_h/Q$, the elasticity of agricultural input supply; and

$\theta^j = (\partial Q/\partial Q^j)Q^j/Q$, the j^{th} firm's conjectural elasticity.[3]

Equation (4) can be rearranged to yield

$$M \equiv p_p - p_h = -p_p\theta^j/\mu + p_h\theta^j/\varepsilon + \partial C^j/\partial Q^j \tag{5}$$

where M is the agricultural price spread. If the j^{th} firm is a price taker in both the agricultural input and output markets, it expects that prices and hence aggregate quantities in these markets will be unaffected by changes in its own quantity. That is, $\theta^j = 0$ and equation (5) reduces to the standard relationship for the competitive case: The price spread is equal to marginal processing cost. If the firm possesses market power, however, it anticipates an increase in market quantity (decrease in output price, increase in input price) in response to an increase in its own quantity. Thus $\theta^j > 0$ and equation (5) shows that the price spread will exceed marginal cost by two positive terms, $-p_p\theta^j/\mu$ and $p_h\theta^j/\varepsilon$, respectively the monopoly and monopsony price distortions. Equation (5)'s decomposition of the marketing margin provides a basis for empirical estimation of the individual components.

III. Aggregation Problems

One obstacle to direct estimation of equations (1) - (4) is the dearth of exhaustive, cross-sectional, firm-specific data on input and output quantities and prices. Certain aggregability assumptions must be maintained so that the theory can be empirically implemented using time series industry data.

Assume that the firms' processing cost functions take the following form:

$$C^j(Q^j, \mathbf{w}) = Q^j C_1(\mathbf{w}) + C_2{}^j(\mathbf{w}) \quad \text{for } j = 1, 2, \ldots, N. \tag{6}$$

That is, fixed costs, $C_2{}^j(\mathbf{w})$, may vary across firms, but marginal processing costs, $C_1(\mathbf{w})$, are constant with respect to output at a value that is common to all firms. Summing versions of equation (3) over firms and letting X_i denote the industry's employment of the i^{th} nonagricultural input, one obtains

$$X_i \equiv \Sigma_{j=1}^{N} x_i{}^j = Q\, \partial C_1(\mathbf{w})/\partial w_i + \Sigma_{j=1}^{N} \partial C_2(\mathbf{w})/\partial w_i \text{ for all i} \tag{3'}$$

In addition, since all firms have the same (constant) value of marginal processing cost, equation (4) guarantees that all will satisfy the profit maximization conditions by choosing the same value of θ^j, θ say.[4] The industry-wide counterpart to equation (4) then becomes

$$p_p(1 + \theta/\mu) - p_h(1 + \theta/\varepsilon) - C_1(\mathbf{w}) = 0 \tag{4'}$$

Equations (3') and (4') show the appeal of a cost function of the type described in equation (6): It permits aggregate factor demands and the condition defining the representative firm's optimal output level to be written in terms of industry variables alone.

One could elaborate on the specification of equation (4') by introducing ad hoc parametrizations of its conjectural elasticity and marginal cost terms. An estimated version of the resulting equation could be rearranged into the form of equation (5) and used to obtain estimates of the individual spread components. Thus, estimation of the parameters embedded in equation (4') is the primary focus. In order to identify separately θ, μ, and ε, however, it would be necessary to incorporate independent information about supply and demand elasticities. Moreover, the precision of the spread component estimates could be improved by subjecting the estimation process to any theoretical restrictions on cost function parameters. One source of such restrictions is the set of aggregate factor demand functions. It is useful, therefore, to estimate equation (4') as part of a system including equations (1) and (2) and versions of equation (3').

IV. Empirical Model

We now turn to an application of the procedures outlined above to the analysis of quarterly data on hog/pork, farm/wholesale margins. The analysis focuses on the <u>hog packing</u> industry, that portion of the pork marketing channel which converts the agricultural input of market-sized hogs to the wholesale product of dressed hog carcasses.

The first step is the specification of functional forms for wholesale pork demand, hog supply, and the processing cost function. Per capita wholesale demand for pork is assumed to be a function of real price, the real price of beef, real per capita income, and quarterly effects.[5]

$$\ln(Q/POP) = \alpha_0 + \mu \ln(p_p/S) + \alpha_1 \ln(p_b/S) + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + \alpha_5 \ln(Y/POP/S) \quad (7)$$

where Q = commercial pork output,

POP = population of the U.S.,

p_p = wholesale price of pork,

S = consumer price index for food items,

p_b = wholesale price of beef,

D_i = a dummy variable equal to 1 in quarter i and 0 otherwise,

and Y = nominal personal income.

Realistic specifications of hog supply must reflect the impacts of historical breeding decisions and anticipated future profit opportunities on current hog marketings. Rather than attempt a formal derivation of hog supply within an intertemporal decision-making framework, we merely posit a plausible specification which incorporates dynamic elements. Current hog marketings, as a proportion of the stock of market-sized hogs, are assumed to be a function of a trend term, and of this quarter's prices of hogs and feed normalized by farmers' expectations of next quarter's price of hogs.[6] Expected next period's price is simply proxied by its actual value.

$$\ln(Q/PC) = \beta_0 + \varepsilon \ln(p_h/p_{h,+1}) + \beta_1 \ln(p_f/p_{h,+1}) + \beta_2 \ln(t) \quad (8)$$

where p_h = price of hogs,

$p_{h,+1}$ = next period's price of hogs,

p_f = price of feed,

PC = stock of marketable hogs,

and t = a time trend.

The industry processing cost function is taken to be a generalized Leontief form appropriate for a processing technology using three inputs: packing plant labor, energy, and transportation services.[7] We let

$$C(Q, \mathbf{w}) \equiv \Sigma_{j=1}^{N} C^j(Q^j, \mathbf{w}) = Q\, \Sigma_i\, \Sigma_k\, b_{ik}(w_i w_k)^{1/2} + \Sigma_i\, b_i w_i \quad (9)$$

where $b_{ik} = b_{ki}$ for i, k = 1,2,3;

$C_1(\mathbf{w}) = \Sigma_i\, \Sigma_k\, b_{ik}(w_i w_k)^{1/2}$;

$\Sigma_{j=1}^{N} C_2{}^j(\mathbf{w}) = \Sigma_i\, b_i w_i$;

w_1 = hog packing labor wage;

w_2 = price of energy;

and w_3 = price of transportation services.

To economize on the number of parameters to be estimated, we maintain the plausible assumption that transportation services are required in fixed proportions; substitution possibilities exist only between labor and energy. This implies $b_{13} = b_{23} = 0$.

A sufficiently reliable nonagricultural input quantity series could be constructed for only one of the three factors, hog packing labor, so the empirical model includes only one version of equation (3'):

$$L = b_1 + (b_{11} + b_{12}(w_2/w_1)^{1/2})Q \qquad (10)$$

where L = the number of production workers employed in hog packing. Given the cost function in equation (9), the corresponding form of equation (4') is

$$p_p(1 + \theta/\mu) - p_h(1 + \theta/\varepsilon) - (b_{11}w_1 + b_{22}w_2 + b_{33}w_3 + 2b_{12}(w_1w_2)^{1/2}) = 0 \qquad (11)$$

Finally, since equilibrium conjectural variations are likely to vary with market conditions, it is reasonable to expect θ to be a function of the model's exogenous variables. Development of a formal model establishing the relationship between equilibrium values of θ and market conditions would be a very ambitious task. Thus, here too, we simply posit a specification that is sufficiently flexible to allow complex patterns of variation in θ over time:[8]

$$\theta = \theta_0 + \theta_1 w_1 + \theta_2 w_2 + \theta_3 w_3 \qquad (12)$$

The complete econometric model consists of equations (7), (8), (10), and (11) with θ as given in equation (12).

V. Results and Interpretation

The model jointly determines four endogenous variables (Q, p_p, p_h, and L) so a simultaneous equations technique must be used in estimation. We used iterated three stage least squares (IT3SLS) and quarterly data for the period 1972.IV to 1986.IV.[9] Since initial estimation results supported the hypothesis of serially correlated error terms, we undertook the following two-stage correction procedure. The model's equations were estimated using IT3SLS. The series of residuals were recovered from the pork demand, labor demand, and profit maximization condition equations, and the usual least squares estimates of the AR(1) parameters for the error series were computed. Using these estimates, the equations were expressed in quasi-first differenced form. The biological lags inherent in hog breeding and feeding suggest a three quarter periodicity for errors in this process, however, so the hog supply equation was differenced using a three period lag. The four equations of the model in differenced form were then re-estimated with a second application of IT3SLS. The results of this second stage are reported in Table 1.

Several of the parameters of the demand and supply equations are readily interpretable on an individual basis and have estimated values that conform with theory. The estimate of the own price elasticity of demand for pork, μ, is of the correct sign and highly significant. The significantly positive estimate of α_1 reveals beef to be an important substitute for pork while the significantly negative estimate of α_5 suggests that pork is an inferior good. The estimates of the quarterly demand effects indicate that (relative to the first quarter) the second and third quarters are "low" demand periods while the fourth quarter is a "high" demand period.

The estimate of the elasticity of hog supply, ε, is positive with a marginal significance level of 0.04. Given greater statistical significance, the positive estimate of β_1 would have confirmed intuition suggesting that an increase in feed price, relative to an expectation of next period's hog price, will increase this period's hog marketings.[10]

The primary objective is the decomposition of observed historical price spreads into cost and market power components. Recall equation (5) which, using equation (9), can be rewritten as

$$M = -p_p\theta/\mu + p_h\theta/\varepsilon + \Sigma_i \ \Sigma_k \ b_{ik}(w_i w_k)^{1/2} \qquad (5')$$

The three terms on the right hand side are, respectively, the monopoly, monopsony, and marginal cost components of the margin. Using estimates of the parameters and data on nonagricultural factor prices and p_p and p_h, each of these can be estimated for every time period in the sample. Table 2 displays estimates and asymptotic standard errors for θ and for each of the three margin components for selected quarters in the sample. For example, for the first quarter of 1978, the farm/wholesale price spread of 30.62 cents/wholesale lb. is inferred to contain monopoly and monopsony components of 5.34 and 10.97 cents/lb. respectively. The balance, 14.31 cents/lb., is attributed by this decomposition to the marginal processing costs of hog packing.

The figures in Table 2 reveal abrupt differences in the magnitudes and statistical significance of estimates of θ and the margin components between the first and second halves of the sample. For the 27 quarters between 1972.IV and 1979.II, the estimates of θ are significantly greater than zero at the 2.5% level in all periods and at the 1% level in 24 periods.[11] Monopoly and monopsony component estimates, too, are highly significant and generally sum to figures larger than the corresponding estimates of marginal cost. Noncompetitive behavior apparently prevailed during this period with the result being price spreads that were inflated by significant market power pricing distortions. For the 29 quarters between 1979.IV and 1986.IV, none of the estimates of θ or the monopoly or monopsony power terms are significant at even the 10% level.[12] The hypothesis of price taking conduct cannot be rejected for this period and, consequently, price spreads appear to quite closely reflect marginal costs.[13] Finally, note that these findings could not have been discerned through mere casual analysis of price spreads: The early sample period, marked by significant oligopoly/oligopsony pricing distortions, contains some of the lowest, as well as some of the highest, values of nominal price spreads.

VI. Summary

Implicit in public discussions about agricultural price spreads, or marketing margins, is the concern that a wide or rising spread may be due to the exercise of market power within the food processing industry. This paper adapts a procedure for the empirical assessment of market power to the task of decomposing price spreads into components reflecting the marginal costs of the processing industry and oligopoly/oligopsony price distortions. The empirical model is implemented using data on farm/wholesale spreads for pork for the period 1972.IV to 1986.IV. The principal finding for this particular application is that farm/wholesale margins for pork are more consistent with competitive performance now than they were fifteen years ago. Ward (1987) points out, however, that very recent acquisitions and mergers in the industry may soon have adverse effects on performance. It will be interesting, therefore, to use our approach to track margin components beyond 1986.IV as data become available. Moreover, a decomposition of wholesale/retail pork margins would be a useful application of the technique since it could reveal the source of the nearly six-fold increase in these margins since 1972.

Data Appendix

Data on the model's variables were collected from U.S. government publications Livestock and Poultry Situation, Livestock and Meat Statistics, Employment and Earnings, Economic Report of the President, Agricultural Outlook, Current Population Reports, and Monthly Energy Review; and from the Annual Financial Review of the American Meat Institute (see references).

Q = commercial pork production in the U. S. (million lbs., carass weight)

POP = resident population of the U. S. (thousands)

p_p = wholesale (carcass) price of pork (cents/lb.)

S = consumer price index, food items (1967 = 100)

p_b = price of carcass beef minus carcass by-product allowance (cents/lb.)

Y = U. S. nominal personal income (billions of dollars, annual rate)

p_h = market value to the producer of 1.6038 lbs. live hog (equivalent to 1 lb. wholesale) minus by-product allowance (cents./lb.)

p_f = wholesale price of No. 2 yellow corn, Chicago ($/bu.)

PC = quarterly pig crop 7 months prior to date t (1000 head)

w_1 = production worker average hourly earnings in SIC 2011 ($/hour)

w_2 = average retail electricity prices to industrial customers (cents/kilowatt hour)

w_3 = wholesale price of No. 2 diesel fuel (cents/gal., tax excluded)

L = production workers in hog packing plants (thousands, 40 hour/week equivalents)

Values for L were estimated using information on: 1) the number of production workers (in 40 hour/week equivalents) in SIC 2011 (meat packing), 2) commercial production of pork and of all red meat, and 3) the relative productivities of labor in hog and cattle packing.

Notes

[1]A straightforward interpretation of margins as indices of processing industry performance requires that the production relationship between the input and output be one of fixed proportions. This is a reasonably accurate assumption for hog packing, the subject of this study, as well as for cattle and lamb packing, flour milling, and grain meal and oil processing.

[2]Studies of price spreads in the agricultural economics literature include Berck and Rausser (1982); Chambers (1983); Gardner (1975); Hall, Schmitz, and Cothern (1979); Heien (1980); and Wholgenant (1985).

[3]Many recent studies have used conjectural variations as a device for parametrizing the nature of the oligopoly equilibrium in an industry. Cowling and Waterson (1976), and Clarke and Davies (1982) have used the concept to explore theoretical aspects of price-cost margins and market structure. Empirical applications include Appelbaum (1982), Roberts (1984), and Schroeter (1988). The present development is an adaptation of the approach used in Appelbaum (1982).

[4]This does not mean that all firms will produce the same output or that all have the same conjectural variation functions; merely that all will choose to operate where θ values are equal.

[5]The appendix provides precise definitions and details concerning measurement of the variables introduced in this section.

[6]The supply "model" we have in mind examines the problem of a producer with hogs that may be either marketed this period or fed for one more quarter. The higher is this period's hog price or the higher is the price of feed, relative to an expectation of next period's hog price, the greater will be the proportion of marketable hogs sold rather than carried over. Thus, our price

elasticity of supply reflects a "marketing" response to price changes rather than a "breeding" response. Normalizing current hog prices by an expected future price also avoids a practical problem first elucidated by Myers and Havlicek (1967). Since marketings this period are inversely related to next period's expected price and this period's and next period's prices are positively correlated, attempts to estimate the short-term supply of live stock for slaughter as a function only of current price frequently produce spuriously negative supply responses.

[7]See Diewert (1974) for a discussion of the generalized Leontief cost function and its properties.

[8]This follows Appelbaum's (1982) approach of modelling the equilibrium conjectural elasticity as a function of exogenous factor prices.

[9]Gallant (1977) and Gallant and Jorgenson (1979) provide the distribution theory for the IT3SLS estimator. The instrumental variables used in the analysis are identified in a footnote to Table 1.

[10]The generalized Leontief function is linearly homogeneous by construction and, for the estimated parameter values, monotonic in w_1 at every sample point. Concavity in factor prices requires $b_{12} > 0$, but this hypothesis is easily rejected. The fact that only some of the theoretical restrictions on cost parameters could be imposed in estimation (again, data limitations permitted estimation of but one conditional factor demand curve) may be responsible for the violation of the curvature conditions.

[11]The estimates of conjectural elasticities for this period are roughly comparable to ones that Schroeter (1988) and Appelbaum (1982) found for the beef packing and textile industries respectively.

[12]For 17 of these periods, estimates of θ and, therefore, the market power components are negative. In no case, however, are these negative estimates significant. (The t-values are all less than 0.6 in absolute value). Negative conjectural elasticities have no economically meaningful interpretation. Nonetheless, negative estimates can occur because we chose a simple linear specification for θ rather than one which constrained values to be non-negative.

[13]Nelson (1985) reports that the four firm concentration ratio in hog packing had increased from 32% in 1972 to about 36% in 1982.

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Table 1
IT3SLS Estimation Results[a]
Sample = 1972.IV - 1986.IV[b]

μ	-0.5452	ε	0.1901	b_{22}	0.7007
	(0.0690)		(0.1043)		(4.4966)
α_0	0.3836	β_0	0.0135	b_{33}	0.3374
	(0.7534)		(0.0173)		(0.2524)
α_1	0.2493	β_1	0.0545	θ_0	0.0564
	(0.0643)		(0.0577)		(0.0221)
α_2	-0.0129	β_2	-0.0464	θ_1	0.0004
	(0.0081)		(0.0586)		(0.0019)
α_3	-0.0260	b_1	-5.4399	θ_2	-0.0054
	(0.0088)		(2.9631)		(0.0083)
α_4	0.0810	b_{11}	0.0306	θ_3	-0.0004
	(0.0082)		(0.0022)		(0.0004)
α_5	-0.6544	b_{12}	-0.0190		
	(0.2222)		(0.0034)		

Equation	R^2 [c]
(7) Pork demand	0.897
(8) Hog supply	0.126
(10) Labor demand	0.966
(11) Profit max condition	0.958

[a] Results of estimation of the model in differenced form. Instruments included the exogenous variables in the supply and demand equations, nonagricultural factor prices, an index of prices received by farmers, and a cattle price variable. Asymptotic standard errors are reported in parentheses.

[b] Number of observations = 57.

[c] R^2's are for the equations of the model in differenced form. They report the squared simple correlations between actual and fitted series of $\ln(Q/POP)$, $\ln(Q/PC)$, L, and p_p; for equations (7), (8), (10), and (11) respectively.

Table 2
Price Spread Decomposition for Selected Quarters[a]

Quarter	Conjectural Elasticity θ	Margin[b]	Monopoly Component[c] $-p_p\theta/\mu$	Monopsony Component[c] $p_h\theta/\varepsilon$	Marginal Cost Component $\Sigma\Sigma\ b_{jk}(w_j w_k)1/2$
1973.I	0.0470	26.37	7.14	14.06	5.17
	(0.0177)		(2.71)	(2.99)	(2.08)
1974.II	0.0389	23.94	4.94	8.78	10.22
	(0.0146)		(1.88)	(1.88)	(1.66)
1975.III	0.0350	36.54	7.99	16.61	11.93
	(0.0135)		(3.12)	(3.90)	(2.41)
1976.IV	0.0334	27.04	5.29	9.21	12.54
	(0.0132)		(2.12)	(2.30)	(2.98)
1978.I	0.0294	30.62	5.34	10.97	14.31
	(0.0125)		(2.30)	(3.26)	(3.94)
1979.II	0.0215	31.02	3.72	7.18	20.12
	(0.0097)		(1.71)	(2.44)	(3.17)
1980.III	0.0052	33.09	0.98	1.90	30.22
	(0.0101)		(1.90)	3.65)	(5.35)
1981.IV	-0.0044	33.95	-0.80	-1.47	36.23
	(0.0131)		(2.39)	(4.34)	(7.02)
1983.I	-0.0008	30.63	-0.16	-0.34	31.13
	(0.0093)		(1.92)	(4.07)	(5.45)
1984.II	-0.0011	30.76	-0.22	-0.44	31.42
	(0.0094)		(1.77)	(3.58)	(5.29)
1985.III	0.0004	29.21	0.07	0.14	29.00
	(0.0119)		(1.97)	(4.11)	(6.91)
1986.IV	0.0154	27.68	3.11	6.46	18.11
	(0.0201)		(4.08)	(8.26)	(11.80)

[a] Asymptotic standard errors appear in parentheses.

[b] The "Margin" column contains fitted values of the farm/wholesale margin which will not exactly match measured values. The margin and its components are each dimensioned in cents/wholesale lb.

[c] The standard errors of the monopoly and monopsony components were computed treating the actual values of p_p and p_h as constants.

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