Market Power and its Effects on Equilibrium in the Food System

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Abstract

When food processors have conjectures about rival firms' responses, their profit functions can be used to estimate the degree of market power in the food system. The effects of this power are investigated analytically and through applying the results to the U.S. pork sector.

Introduction

The acquisition and abuse of market power are controversial features of the U.S. food-marketing system. The malallocation of resources and the perceived inequities that stem from the noncompetitive conduct of marketing firms has been a perennial concern of agricultural economists (Marion, Mueller, Marion and Mueller). The food-marketing industries--the industries that assemble and process farm commodities and distribute food products to consumers--are a key link in the food system. Their activities have direct impacts on the profitability of farming, the profitability of food marketing itself, and the welfare of consumers. It is thus important to determine the extent of market power and to estimate its effects on equilibrium in the food system.

Attempts to measure the effects of market power in the food processing industries have been controversial (Parker and Connor, O'Rourke and Greig, Gisser, Marion and Grinnell, Kenney, Hazeldine and Cahill). The focus of these attempts has been to determine the sizes of the deadweight loss and the income transfers that have occurred; there has been little emphasis on determining the effects of market power on equilibrium in the system. This paper presents an approach to measuring market power that can be used to determine the effects of this power on the equilibrium prices and quantities of goods that are traded in food markets. The next section proposes a model of a food subsector. A representative firm's problem is examined and a method is developed for estimating the firm's degree of market power. The firm's behaviour is then integrated into the food subsector and the comparative static properties of the resulting equilibrium are investigated. The importance of certain parameters are highlighted through the introduction of a specific, parametric example and through an application of the results to the U.S. pork sector.

Marketing Firm Equilibrium and the Measurement of Market Power

Gardner has developed a framework that has been used extensively to analyze food-system equilibrium. The model depicts an equilibrium in which food processors do not take account of their possible interactions. It assumes that firms take prices as given and produce a food product by combining marketing inputs with a farm commodity through a linearly homogeneous technology. The model presented below extends this framework by allowing firms to recognize their effect on prices through their effects on the quantity decisions made by other firms. The concept through which this is applied is that of conjectural variations (Kamien and Schwartz).

Consider the following marketing system for a food product. A farm industry produces a commodity, Q_f, from an aggregate input, Q_z, using a technology: $Q_f = G(Q_z)$, where $\partial G(\cdot)/\partial Q_z > 0$, and $\partial^2 G(\cdot)/\partial Q_z^2 < 0$. A processing industry combines the farm commodity with quantities of marketing services, Q_m, through a technology $H(\cdot)$, to produce a retail product, Q_r. Let p_a, $a=f,m,r,z$, denote the price of good a, and let the superscripts $j=1,2...m$ and $i=1,2...n$ index, respectively, the m firms in the processing industry and the n firms in the farm industry. Denoting firm-level quantities by lower-case letters, the maximal profits of a representative farm firm are given by:

$$\text{(1)} \qquad \pi^i(p_f,p_z) \equiv \max \{ p_f q_f^i - p_z q_z^i \ ; \ q_f^i \leq G(q_z^i) \},$$

where $\pi^i(p_f,p_z)$ is linearly homogeneous in p_f and p_z and satisfies

$$\text{(2)} \qquad \partial\pi^i(\cdot)/\partial p_f = q_f^i.$$

Assume that firms are identical, aggregate supply is simply:

$$(3) \qquad Q_f = \sum_{i=1}^{n} q_f^i = \sum_{i=1}^{n} \partial\pi^i(\cdot)/\partial p_f = n\,\partial\pi^i(\cdot)/\partial p_f \equiv \Pi_f^i(p_f, p_z),$$

where $\Pi_f^i(p_f, p_z)$ is homogeneous of degree zero and monotonic in p_f and p_z. This allows derivation of a separable inverse súpply function of the form:

$$(4) \qquad p_f = p_z S_f(Q_f),$$

where $S_f(\cdot) \equiv \Pi_f^i(\cdot)^{-1}$.

The variable p_z will play an important role in the analysis to follow. From (4), it can be construed simply as an exogenous effect that shifts the supply function. Although it has been given the specific interpretation of the farm-input wage rate more general interpretations are possible. For example, if Q_f were a vector of farm outputs and if Q_z were a vector of inputs, by imposing a specific form of separability on $G(\cdot)$, p_z could be a linear homogeneous function of the prices of inputs and of the outputs other than the commodity in question (Diewert). In any case, the particular structure assumed on the inverse supply schedule will play a crucial role in measuring the degree of market power.

In an analogous manner, the inverse supply of marketing services can be derived as:

$$(5) \qquad p_m = p_x S_m(Q_m),$$

where $S_m(\cdot)$ is monotonic in Q_m, p_m is the per-unit cost of marketing services, and p_x is an exogenous variable that shifts the supply function--for example, the wage rate paid by firms supplying marketing services to the processing industry.

Similarly, the inverse-demand schedule for the food product is:

(6) $p_r = yD(Q_r)$,

where p_r is the price of the product and y is a variable that shifts the demand function. In this case, y could simply be disposable income, or it could be expenditure allocated to food, or it could be a linear homogeneous function of the prices of other goods.

Consider the situation in which a processing firm behaves competitively in its factor markets but recognizes its ability to influence the price of the product. The firm conjectures how other processing firms will respond to a change in its own output level. These conjectures are relationships that can be given a functional interpretation; they tell the firm how the common prices that face all firms will adjust to a change in that firms own quantities. The firm solves

(7) $\max \pi^j = p_r q_r^j - C(p_f, p_m, q_r^j)$,

where $C(p_f, p_m, q_r^j) \equiv \min\{ p_f q_f^j + p_m q_m^j;\ q_r^j \leq H(q_f^j, q_m^j) \}$ and is common to all firms. This problem yields a first-order condition:

(8) $p_r + [\partial p_r/\partial Q_r \cdot \partial Q_r/\partial q_r^j]\, q_r^j = \partial C(\cdot)/\partial q_r^j$.

Expanding the second term in the parentheses on the left-hand side gives

(9) $\partial Q_r/\partial q_r^j = 1 + \sum_{k \neq j}^{m} \partial q_r^k(q_r^j)/\partial q_r^j$,

which denotes the fact that firm j perceives a response to its own decisions from the other m-1 firms in the industry. To denote this explicitly, write $Q_r = q_r^j + \sum_{k \neq j}^{m} q_r^k(q_r^j) \equiv R^j(q_r^j)$.

Suppose, as we did at the farm level, that firms are identical and, in addition, that firm j believes that the responses take the form: $q_r^k = \lambda q_r^j$, $\forall k = 1,2...m, k \neq j$; where λ is a constant that satisfies $\lambda \in [1/(1-m),1]$. When the firm conjectures $\lambda = 1/(m-1)$, it believes that the other m-1 firms will adjust their outputs to accomodate firm j's actions and thus, from (9), it believes $\partial Q_r/\partial q_r^j = 0$, which is equivalent to behaving competitively. In contrast when $\lambda = 1$, the firm believes that a change in its own output is matched perfectly by changes in the output of the other m-1 firms and thus it conjectures $\partial Q_r/\partial q_r^j = m$. When each firm conjectures in this manner the industry as a whole behaves as a perfect cartel. When firm j conjectures that the remaining firms are unresponsive to a change in its own output $\lambda = 0$ and the Cournot response is obtained with $\partial Q_r/\partial q_r^j = 1$.

Let $\theta \equiv (\partial Q_r/\partial q_r^j).(q_r^j/Q_r)$ be the elasticity of industry output conjectured with respect to the output of firm j, and let $\eta \equiv (\partial Q_r/\partial p_r).(p_r/Q_r)$ be the elasticity of demand for the retail product. Then, (8) can be rewritten as:

$$(10) \qquad p_r[\, 1 + \theta/\eta \,] = \partial C(\cdot)/\partial q_r^j.$$

From this we define the degree of market power of firm j as the value θ/η. The latter represents a "wedge" between the market price and the price that would prevail if the firm perceived itself to have no market power. This follows from the fact that $\theta = 0$ when the firm behaves competitively. Similarly, in the perfect cartel case $\theta = 1$ and (10) represents the first-order condition for a pure monopolist. When firms behave as Cournot oligopolists an intermediate case is obtained with $\theta = q_r^j/Q_r$, which is firm j's share of industry output. It is worth emphasizing that the elasticity of demand is a crucial determinant of the degree of market power because $\lim_{\eta \to -\infty} p_r = \partial C(\cdot)/\partial q_r^j$, which is independent of the value of θ. Moreover, η severely constrains the domain of the firm's conjectures, in fact $\theta \in [0,|\eta|)$ in view of the nonegativity of the right-hand side of (10).

Recalling the definition of the inverse demand schedule, it is clear that the exogenous variable y will enter the firm's profit function: $\pi^j(y,p_f,p_m) \equiv \max \{ p_r q_r^j - C(p_f,p_m,q_r^j) ; p_r = yD(Q_r), Q_r = R^j(q_r^j) \}$. By analogy, when the firm has conjectures, $Q_f = F^j(q_f^j)$ and $Q_m = M^j(q_m^j)$, about how aggregate industry demands adjust to a change in the demands of firm j, its maximal profits are given by

$$\text{(11)} \quad \pi^j(y,p_x,p_z) = \max \{ p_r q_r^j - p_m q_m^j - p_f q_f^j; \quad q_r^j \le H(q_m^j,q_f^j) \\ p_r = yD(Q_r), \quad p_m = p_x S_m(Q_m), \quad p_f = p_z S_f(Q_f), \\ Q_r = R^j(q_r^j), \quad Q_m = M^j(q_m^j), \quad Q_f = F^j(q_f^j) \}.$$

The following will be useful in empirical applications.

__Proposition__: Under assumption, $D(\cdot)$, $S_m(\cdot)$, $S_f(\cdot)$, $R^j(\cdot)$, $M^j(\cdot)$, and $F^j(\cdot)$, are each nonnegative and continuous; then the function $\pi^j(y,p_x,p_z)$ is nonincreasing in p_x and p_z, respectively; nondecreasing in y; and homogeneous of degree one, convex, and continuous in p_x, p_z, and y.

__Proof__: Follow Sakai's development of the variable profit function.

__Lemma__: Applying the envelope theorem in (11) yields normalized revenue and factor costs as the first-order partial derivatives of $\pi^j(y,p_x,p_z)$:

$$\partial\pi^j(y,p_x,p_z)/\partial y = p_r q_r^j/y = D(Q_r)q_r^j = D(R^j(q_r^j))q_r^j,$$
$$-\partial\pi^j(y,p_x,p_z)/\partial p_x = p_m q_m^j/p_x = S_m(Q_m)q_m^j = S_m(M^j(q_m^j))q_m^j,$$
$$-\partial\pi^j(y,p_x,p_z)/\partial p_z = p_f q_f^j/p_z = S_f(Q_f)q_f^j = S_f(F^j(q_f^j))q_f^j.$$

Once appropriate forms are selected for the functions $D(\cdot)$, $S_m(\cdot)$, $S_f(\cdot)$, $R^j(\cdot)$, $M^j(\cdot)$, and $F^j(\cdot)$ the system above is observable empirically. Moreover, a judicious choice of the conjectural variations functions will yield statistical tests of the null hypotheses of perfect competition in output and factor markets.

Rather than estimate these equations, we apply the concept of the conjectural variations profit function to determine the effects of market power on equilibrium in the food system.

The Comparative Statics of Food System Equilibrium

The parameters of the profit function are important determinants of the way that exogenous shocks are distributed throughout the food marketing system. Equilibrium for the food subsector can be expressed through

$$(12)\quad \begin{cases} p_r = yD(Q_r); \\ Q_r = mq_r^j; \\ q_r^j = (y/p_r)\ \partial\pi^j(y,p_x,p_z)/\partial y, & j=1,2,\ldots m; \\ q_m^j = -(p_x/p_m)\ \partial\pi^j(y,p_x,p_z)/\partial p_x, & j=1,2,\ldots m; \\ q_f^j = -(p_z/p_f)\ \partial\pi^j(y,p_x,p_z)/\partial p_z, & j=1,2,\ldots m; \\ Q_f = mq_f^j; \\ p_f = p_z S_f(Q_f); \\ Q_m = mq_m^j; \\ p_m = p_x S_m(Q_m). \end{cases}$$

There are 3m+6 endogenous variables: the supply of output (q_r^j) and the demands for the two inputs (q_f^j and q_m^j) for each of the m firms in the marketing industry; and the prices (p_r, p_m, and p_f) and aggregate quantities (Q_r, Q_m, and Q_f). This system is easily reduced to the following:

$$(13)\qquad \begin{bmatrix} (1+1/\eta) & 0 & 0 \\ 0 & (1+1/\xi) & 0 \\ 0 & 0 & (1+1/\epsilon) \end{bmatrix} \begin{bmatrix} \tilde{Q}_r \\ \tilde{Q}_f \\ \tilde{Q}_m \end{bmatrix} = \begin{bmatrix} e_{yy} & e_{yz} & e_{yx} \\ e_{zy} & e_{zz} & e_{zx} \\ e_{xy} & e_{xz} & e_{xx} \end{bmatrix} \begin{bmatrix} \tilde{y} \\ \tilde{p}_z \\ \tilde{p}_x \end{bmatrix},$$

where tildes, "~", represent percent changes (i.e., $\tilde{x} = dx/x$); $\eta \in (-\infty,0)$ is the elasticity of retail demand, $\xi \in (0,\infty)$ is the elasticity of farm supply, and $\epsilon \in (0,\infty)$ is the elasticity of supply of the marketing service input; and $e_{st} \equiv (\partial^2\pi^j(\cdot)/\partial s\partial t)(t\partial\pi^j(\cdot)/\partial s)$, where s and t index the shift parameters y, p_x, and p_z. Thus, through the terms e_{st}, the parameters of the profit function play a crucial role in the displacements of variables to new equilibria. In particular, the effects on the price and quantity of the farm commodity of shifts in (i) the supply of marketing services, and (ii) the demand for the retail product, are given, respectively, by:

$$(14)\qquad \begin{cases} \tilde{Q}_f = \xi\, \tilde{p}_x\, e_{zx} / (1+1/\xi), \\ \tilde{p}_f = \tilde{p}_x\, e_{zx} / (1+1/\xi), \\ \tilde{Q}_f = \xi\, \tilde{y}\, e_{zy} / (1+1/\xi), \\ \tilde{p}_f = \tilde{y}\, e_{zy} / (1+1/\xi). \end{cases}$$

A Specific Example and Application to the U.S. Pork Sector

A parametric example will help to develop the notion of the processor's conjectural variations profit function. Suppose the inverse demand and supply functions are given, respectively, by $p_r = yQ_r^{1/\eta}$, $p_f = p_zQ_f^{1/\xi}$, and $p_m = p_xQ_m^{1/\epsilon}$. Suppose that the firm's conjectures can be approximated in constant elasticity form as: $Q_r = (q_r^j)^\theta$, $Q_m = (q_m^j)^\beta$, and $Q_f = (q_f^j)^\alpha$. In addition, suppose that the firms technology is of the generalized Cobb-Douglas form: $Q_r = (q_f^j)^\gamma(q_m^j)^{\rho-\gamma}$, where ρ is the degree of returns to scale. After some tedious algebra (available from the authors upon request) the firm's profit function can be derived as:

$$(15) \qquad \pi^{j}(y,p_x,p_z) = T\, y^{\Gamma}\, p_z^{\Phi}\, p_x^{\Sigma},$$

where: $T = [(\delta/\lambda)^{\delta\omega}(\tau/\omega)^{\tau\lambda}]^{\phi} - [(\tau\lambda/\delta\omega)^{\tau\lambda}(\delta/\lambda)^{\lambda\omega}]^{\phi} - [(\delta\omega/\lambda\tau)^{\delta\omega}(\tau/\omega)^{\lambda\omega}]^{\phi}$,

$\Gamma = \lambda\omega\phi$, $\Phi = -\delta\omega\phi$, $\Sigma = -\tau\lambda\phi$, $\phi = 1/(\lambda\omega-\delta\omega-\tau\lambda)$, $\delta = \gamma(1 + \theta/\eta)$,

$\tau = (\rho-\gamma)(1 + \theta/\eta)$, $\lambda = (1 + \alpha/\xi)$, and $\omega = (1 + \beta/\epsilon)$.

It can be shown that $\pi^{j}(y,p_x,p_z)$ is linearly homogeneous in p_z, p_x, and y, and that montonicity is satisfied. Convexity requires conditions on Γ, Φ, and Σ that reduce to:

$$(16) \qquad \frac{(1+\alpha/\xi) + (1+\beta/\epsilon)}{(1 + \theta/\eta)} \geq \rho.$$

This places restrictions on the degree of returns to scale in processing. It shows that the scale factor is bounded above by a combination of the degrees of market power in the firm's factor and product markets. This condition will be used below in the application of (15) to the U.S. pork sector.

An important issue is the extent to which profits derived from favorable demand and supply shifts are passed back to the farm industry. More specifically, the extent to which market power may affect these movements is an important item for public policy; after all, if market power has little effect, the actual degree of market power may be only of academic interest. To analyze this issue, we revisit the situation in the U.S. pork sector in 1980 and introduce the possibility that hog processors possess market power in the farm commodity and processed product markets. The choice of example is motivated by its previous use in illustrating the distribution of the gains from downstream research in competitive marketing systems (Freebairn et al., Alston and Scobie).

The focus here is on the farm gains of two types of exogenous effects: (i) a ten percent reduction in the cost of marketing services, and (ii) an equivalent per-unit shift outward in the retail demand schedule. Throughout the analysis processors are assumed to face a perfectly elastic supply of marketing services and constant returns to scale is assumed.

From the inverse supply function for the farm commodity, the change in producer surplus that results from an exogenous, downstream shock is:

$$(17) \quad \Delta PS = p_f Q_f(\tilde{p}_f + \tilde{Q}_f + \tilde{p}_f \tilde{Q}_f) - p_z Q_f^{(1+1/\xi)}[(1 + \tilde{Q}_f)^{(1+1/\xi)} - 1]/(1+1/\xi).$$

The expressions for the percent changes are given in (14). Table 1 presents the data necessary to implement these formulae and table 2 presents the results of the two experiments. The figures, which are normalized on the maximum farm gain ($237 million), show that, although farm benefits accrue to both types of effects over the domain of the parameters α and θ, the values of the parameters significantly affect the magnitude of the gains. The latter decline with increases in the degree of market power in both markets. The most accute effect occurs when there is a shift in retail demand. When the degree of monopsony power in the farm commodity market is 0.2, and processors act collusively in the product market to generate $\theta = 0.75$, the farm gains are only 0.008 as large as those that would obtain had there been perfect competition in supplying the processed product.

These results have important implications for competition policy in the food industries. Of course, the actual magnitudes of the effects of market power remains an empirical question; its resolution awaits data collection and formulation of a specific, estimable form for the variable profit function specified in equation (11).

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Table 1. Values of Variables for the U.S. Hog Industry

Variable	Value	Description
Q_f	13,209 million pounds	quantity of farm product[a]
p_r	\$1.436	price of retail product in dollars per pound[a]
p_f	\$0.766	price of farm product in dollars per pound[a]
p_m	\$0.670	cost of marketing services in dollars per unit[a]
γ	0.533	revenue share of farm product[a]
ξ	0.7	elasticity of supply of hogs[a]
η	-0.8	retail demand elasticity[a]
ρ	1.0	returns to scale in processing[b]
ϵ	$+\infty$	marketing services supply elasticity[b]
α	{0.00, 0.20, 0.40, 0.60, 0.80, 1.00}	market power in farm input market[b]
θ	{0.00, 0.15, 0.30, 0.45, 0.60, 0.75}	market power in retail product market[b]
$\tilde{p}_x$	0.10	reduction in marketing services supply[b]
$\tilde{y}$	0.05334262	equivalent per unit shift in retail demand[c]

[a]From table 1 in Alston and Scobie (p. 355).
[b]By assumption.
[c]Calculated from: $\tilde{y}p_r = -\tilde{p}_x p_m$.

Table 2. Farm Benefits in U.S. Hog Sector when Retail-Demand or Marketing-Services Supply Shift by Equivalent Per-Unit Amounts

Shift Out in Retail Demand ($\tilde{y}$)

α	θ 0.00	0.15	0.30	0.45	0.60	0.75
0.00	---[a]	0.511	0.196	0.091	0.039	0.008
0.20	1.000	0.337	0.164	0.084	0.038	0.008
0.40	0.609	0.277	0.148	0.079	0.036	0.008
0.60	0.479	0.247	0.139	0.077	0.036	0.008
0.80	0.415	0.229	0.133	0.075	0.036	0.008
1.00	0.376	0.216	0.129	0.074	0.035	0.008

Shift Down in Marketing Services Supply ($\tilde{p}_x$)

α	θ 0.00	0.15	0.30	0.45	0.60	0.75
0.00	---[a]	0.629	0.314	0.209	0.157	0.125
0.20	0.999	0.415	0.262	0.191	0.151	0.124
0.40	0.609	0.341	0.237	0.182	0.147	0.124
0.60	0.479	0.304	0.222	0.175	0.145	0.123
0.80	0.414	0.281	0.213	0.171	0.143	0.123
1.00	0.376	0.266	0.206	0.168	0.142	0.123

[a]The profit function is not defined when ρ=1, and θ and α are both zero.