Testing for Noncompetitive Behavior in the U.S. Food Industry

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Empirical evidence suggests the existence of noncompetitive markets in several subsectors of the U.S. food industry (SIC 20) (Espinosa and Love; Azzam). Potential welfare loss resulting from these distortions has led to an extensive literature addressing market structure and possible social losses.

Most analyses concentrate on one food industry and parametrically estimate price distortion arising from market power. However, these estimates are dependent upon functional form selected and an underlying behavioral model. As Varian argues, disentangling hypotheses concerning behavior, market structure, and functional form is difficult. Consequently, he argues for first establishing consistency of one's data with a behavioral hypothesis. If, for example, observed production sets are consistent with the weak axiom of profit maximization (WAPM), then the second step of estimating a profit function is appropriate. If the data fail to satisfy WAPM, then a profit function is inappropriate and an alternative behavioral assumption consistent with the data should be found.

In this paper, price distortions arising from market power exertion will be investigated for 47 subsectors of the U.S. food processing sector using nonparametric techniques. The approach allows for both Hicks-neutral and biased technological change. A series of tests are performed using linear programming techniques to check for optimizing behavior under a set of increasingly relaxed technological and market structure assumptions.

<u>The Nonparametric Approach to the Measurement of Market Power</u>

Generally, market power is defined as the deviation from marginal cost (MC) or marginal value product (MVP) pricing. All firms other than perfect competitors may have some market power, allowing them the potential to exert some influence on the prices they face. For a monopolistic firm, this implies that the firm has the power to set output price above marginal cost ($p > MC$). In the case of monopsony, market power is characterized by a firm's ability to set an input price lower than its marginal value product ($MVP > r$). One approach to measuring the degree of market power a firm possesses is to measure the extent to which deviates from marginal revenue. The resulting Lerner index is the percentage by which price exceeds marginal cost:

Monopoly: $$L = \frac{P - MC}{P}.$$ Monopsony: $$L = \frac{MVP - r}{r}$$

In a perfectly competitive situation, price is equated to MC (or MVP) and the Lerner index equals zero. As P (or r) becomes large relative to MC (MVP), the Lerner index approaches one. The greater the value of the Lerner index, the greater the potential for monopoly/monopsony power.

The Lerner index can also be expressed in terms of elasticity of demand. Profit maximizing behavior implies that marginal revenue equals marginal cost and $MR = P(1+1/\eta) = MC$, where η denotes the elasticity of demand. The Lerner index then becomes:

$$L = \frac{P - MC}{P} = \frac{P - P(1 + 1/\eta)}{P} = -\frac{1}{\eta} \quad . \tag{1}$$

Notice that, the less elastic the demand, the higher the Lerner index and the higher the degree of market power.

A similar derivation results in the Lerner for the input market:.

$$\boldsymbol{L} = \frac{\partial \boldsymbol{C}(\boldsymbol{y}) / \partial \boldsymbol{y} - \boldsymbol{r_n}}{\boldsymbol{r_n}} = \frac{\partial\, \boldsymbol{r_n}(\boldsymbol{x_n})}{\partial\, \boldsymbol{x_n}} \frac{\boldsymbol{x_n}}{\boldsymbol{r_n}} = \frac{1}{\varepsilon} \tag{2}$$

where C(y) is the cost function of the firm, x_n is the quantity of the input presumably purchased in an imperfectly competitive market, $r_n(x_n)$ is the inverse supply function for the nth input, and ε is the elasticity of supply for the n^{th} input.

Consider the profit maximization problem for the firm facing downward sloping demand for its output y and an upward supply function for the n^{th} input:

$$\max_{y_i, x_i, x_{ni}} \Pi_i = p(y_i) y_i - \sum_{k=1}^{n-1} r_k x_{ki} - r_n(x_{ni} + \tilde{x}_n) x_{ni} \tag{3}$$

$$\text{s.t.} \qquad f_i(x_i, x_{ni}) \geq y_i$$

where r_k is the price of input k, x_{ki} is the quantity of input k demanded by firm i, $p(y_i)$ is the inverse demand of the i^{th} firm and the remaining variables are as defined previously. For a technically feasible discrete change in input and output levels, profit-maximizing behavior requires that:

$$\mathrm{p}^{t}\left(\mathrm{y}^{t}-\mathrm{y}^{s}\right)+\mathrm{y}^{s}\left(\mathrm{p}^{t}-\mathrm{p}_{e}^{ts}\right)-\sum_{k=1}^{n-1}\mathrm{r}_{k}^{t}\left(\mathrm{x}_{k}^{t}-\mathrm{x}_{k}^{s}\right)-\mathrm{r}_{n}^{t}\left(\mathrm{x}_{n}^{t}-\mathrm{x}_{n}^{s}\right)-\mathrm{x}_{n}^{s}\left(\mathrm{r}_{n}^{t}-\mathrm{r}_{ne}^{ts}\right) \geq 0 \tag{4}$$

where t and s refer to time periods, and p_e^{ts} and r_{ne}^{ts} reflect producer expectations of prices at time t for quantities y^s and x_n^s. For any input and output set optimally chosen at time t, no other solution, such as (y^s, $\mathbf{x}^s$), will result in higher profit given prices at period t. For observed behavior to be consistent with profit maximizing behavior, this inequality must be satisfied for all s and t.

If the firm is a price taker in all markets, the firm has no influence on the prices by changing quantities it sells or buys. In this case, the inequality reduces to Varian's WAPM. Alternatively, firms may face subjective demand and supply functions, having price expectations p_e^{ts} and r_{ne}^{ts}. The above inequality can be termed the Monopolistic/Monopsonistic Axiom of Profit Maximization (M/MAPM). The problem of whether the data can be rationalized under M/MAPM reduces to the problem of whether expected output and input prices p^{ts} and r^{ts} can be found that satisfy the inequalities.

Let the subjective demand and supply functions be expressed respectively as:

$$p_e^{ts} = p^t - m_i^{ts}(y_i^s - y_i^t) \qquad \text{and} \qquad r_{ne}^{ts} = r^t + n_i^{ts}(x_{ni}^s - x_{ni}^t) \tag{5}$$

where m_i^{ts} and n_i^{ts}, are (respectively) the monopolistic and monopsonistic estimates of market power and correspond to the magnitudes of the slopes of the demand and supply curves joining y_i^t and y_i^s and x_{ni}^t and x_{ni}^s at time t. Substituting the expressions (5) into the inequality of (4) and rearranging yields:

$$p^t(y_i^t - y_i^s) - \sum_{k=1}^{n} r_k^t(x_{ni}^t - x_{ni}^s) - n_i^{ts} y_i^s (y_i^t - y_i^s) - m_i^{ts} x_{ni}^s (x_{ni}^t - x_{ni}^s) \geq 0 \, . \tag{6}$$

Finally, the nonparametric test is modified to permit Hicks neutral technical change in output following the translating hypothesis favored by Cox and Chavas. Technical change parameters (a_i^{t+} and a_i^{t-}) are introduced, resulting in the following linear programming model:

$$\min_{a_i^{t+}, a_i^{t-}, m_i^{ts}, n_i^{ts}} Z_i = \sum_{t=1}^{T} \left(b_p a_i^{t+} + b_n a_i^{t-} + \sum_{s \neq t=1}^{T} (c m_i^{ts} + d n_i^{ts}) \right) \qquad (7)$$

s.t.

$$p^t \left[(Y_i^t - a_i^{t+} + a_i^{t-}) - (Y_i^s - a_i^{t+} + a_i^{t-}) \right] - \sum_{k=1}^{n} r_k^t (x_{ni}^t - x_{ni}^s) -$$

$$n_i^{ts} Y_i^s (Y_i^t - Y_i^s) - m_i^{ts} x_{ni}^s (x_{ni}^t - x_{ni}^s) \geq 0$$

$a_i^{t+} \geq 0, \forall t$, $a_i^{t-} \geq 0, \forall t$, $n_i^{ts} \geq 0, \forall s \neq t$ and $m_i^{ts} \geq 0, \forall s \neq t$

where, following Love and Shumway (1994), $n_i^{ts} = \kappa_i^{ts} (p^t / Y_i^s)$ and $\kappa_i^{ts} = [(p^t - p^s) / (Y_i^t - Y_i^s)](Y_i^s / p^t)$ is the price flexibility of the i^{th} firm's perceived residual demand curve, $m_i^{ts} = \eta_i^{ts} (r_n^t / x_{ni}^s)$, and $\eta_{ni}^{ts} = [(r_n^t - r_n^s) / (x_{ni}^t - x_{ni}^s)](x_{ni}^s / r_n^t)$ is the price flexibility of the perceived residual supply for input n facing firm i, and objection function coefficients b_p, b_n, c, and d are nonnegative weights.

Under profit maximizing behavior, firm i's first order conditions for input n and output are: $\eta_{ni}^{ts} = (MVP_{ni} - r_n) / r_n$, and $\kappa_i^{ts} = -[(p^t - MC_i) / p^t]$. If η_{ni}^{ts} and κ_{ni}^{ts} are simultaneously zero, the above firm exerts no market power in either market. The firm's perceived demand and supply functions are infinitely elastic and the firm will produce output at the level where $p = MC = MR$, and employ factor input n until $MVP_{ni} = r_n$. If η_{ni}^{ts} is zero and κ_{ni}^{ts} is greater than zero but less than one, then, the firm is a monopolist or oligopolist. On the other hand, if η_{ni}^{ts} is greater than zero while κ_{ni}^{ts} is zero, then the firm is a monopsonist or oligopsonist. Finally, if both η_{ni}^{ts} and κ_{ni}^{ts} are greater than zero simultaneously, the firm is considered to have some degree of market power in both markets.

The Data

Annual time series data were downloaded from the National Bureau of Economic Research (NBER) Productivity Database website for 47 Standard Industrial Classification (SIC) industries in the 2-digit classification 20 covering 1958-1994. For each of the industries, a single output price and quantity is used. The output price corresponds to the price deflator for value of shipments and the quantity of output is the ratio of real output to the shipment deflator. Five input measures are used: 1) nonenergy materials, 2) energy, 3) production labor, 4) nonproduction labor and 5) capital.

Results

The first of the series of tests conducted analyzed WAPM without technological change for the sample period and for each industry. The LP problems yielded infeasible solutions for all industries implying that the maintained hypothesis can be firmly rejected (i.e., our data was inconsistent with the hypothesis of profit maximizing behavior with no technical change). The next series of tests allowed technical change to take place in all industries in the sample. For all the industries, it was found that the data was consistent with the specification of Hicks-neutral technology. Finally, the potential for bias in input specification was incorporated. In this case, the maintained hypothesis could also not be rejected. Hence, both. Hicks-neutral and biased technical change hypotheses were found to be consistent with the observed data.

Tests of Market Power

For the 47 industries considered, evidence suggested that all have some amount of market power.[1] Table 1 provides the average annual estimates of the monopoly/monopsony Lerner indexes. Poultry slaughter (SIC 2015), for example, had an estimated average markup of 10.18% of output price over MC and a 2% markdown of material input price under MVP over the 37 year period. The highest markup was 57.39% in the Bottled and Canned Soft Drinks and Carbonated Waters (SIC 2086) and the highest value markdown in the input market was 2% in SIC 2015. Six industries were identified as having monopoly power alone. No industry seemed to have market power in the input side only. However, a few industries appear to have had insignificant control over the prices in either the output and/or input side, perhaps due to the relatively small sizes of these industries.

Sample Results: Meat Packing

The beef packing (2011) industry has been extensively analyzed in the literature. Annual results for this industry is discussed to illustrate the sample results.

Moderate distortion from competitive pricing was found in the beef packing industry in both output and input (nonenergy material) markets. The same conclusion was reached by Azzam and Pogolatous (1990).

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[1] The calibration process required choice of suitable weights for the model. In this experiment, we used the weights $bp = bn = 1$, and $c = d = 10^6$.

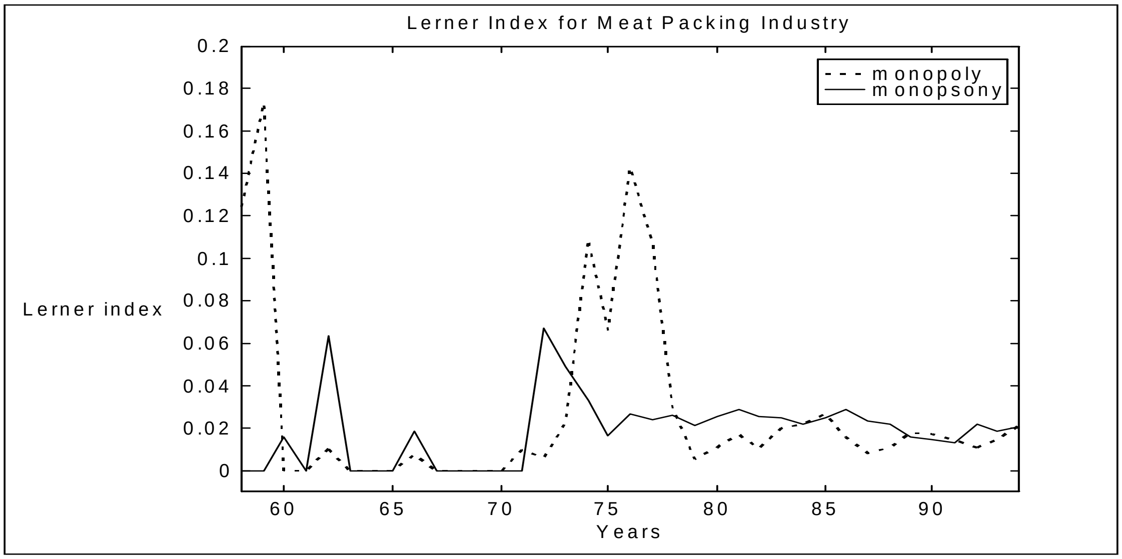

Figure 1. Lerner indexes for meat packing (SIC 2011).

Between 1961 to 1971, the input and output pricing distortions appear to have moved together. Peaks simultaneously occurred in 1962 and 1966. However, from 1974 to 1978, the industry appears to have had significantly higher monopoly power than monopsony. This was a period of rapidly increasing per capita beef consumption. Retail weight consumption increased from 80.5 pounds in 1973 to 94.2 pounds in 1976. By 1979, per capita consumption had fallen to 78.0 pounds. In 1979, monopoly power fell by 83 percent and has since remained relatively steady. Interestingly, the monopsony power has been fluctuating within 25 percent level for more than a decade, and also has been consistently above the monopoly power during the observed period. Both estimates, however, are small since 1979, indicating little apparent price distortion in this industry.

Deadweight Loss Estimates

Table 1 also contains estimates of the deadweight loss to U.S. consumers and the material input suppliers from market power in the food processing sector. Without additional information on costs and production, constant MC and MVP functions were assumed and Harberger triangles were calculated given the slopes of the output demand and input demand curves resulting from solution of the LP problems. The estimates indicate significant losses in some industries. For instance, an average $5 billion loss was estimated in the Bottled and Canned Soft Drinks and Carbonated Waters (BCSDCW) industry over the sample period. This was the largest amount observed. Meat packing losses were about $585 and $369 million in the output and material input markets, respectively. Several industries (e.g., SIC 2083, 2097) had small losses in one or both markets, reflecting either the small markets in which these firms operate and/or small calculated values of the Lerner indexes.

<u>Summary</u>

Nonparametric procedures were developed in this paper to determine market power exertions by industries in SIC 20. The existing nonparametric tests were expanded in two ways. First, the concept of subjective demand was used to derive the M/MAPM and then imbedded in the hypotheses of linear demand and supply functions for the tests of market power. Second, welfare measures arising from market power were calculated using the knowledge of the slopes of the demand and supply functions. For the sample period and for each industry evidence of noncompetitiveness was found.

Six industries were characterized as monopolies only and the remaining 41 had some degree of market power in both input and output markets. The degrees of power varies from low to almost none. These results confirmed the hypothesis of Hick's neutral technical change as well as price distortions in the industries.

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Table 5.2 Annual Average Lerner Indexes and Deadweight Losses ($millions), 1958-1994

		Output Market		Material Input Market	
		Lerner Index	Deadweight Loss	Lerner Index	Deadweight Loss
2011	Meat packing	0.0283	585	0.0183	369
2013	Sausages	0.2971	1167	0.0151	82
2015	Poultry Slaughter	0.1018	327	0.0200	40
2017	Not available	0.0210	18	0.0069	2
2021	Creamy Butter	0.0204	22	0.0000	.02
2022	NPT Cheese DCED P	0.5714	2883	0.0020	9
2023	DCED Products	0.1410	334	0.0004	.6
2024	ICF Deserts	0.0354	66	0.0003	.3
2026	Fluid Milk	0.0441	406	0.0016	11
2032	Canned Specialties	0.0814	190	0.0018	2
2033	CFVPJJ	0.1091	603	0.0014	4
2034	DDFVSM	0.0134	11	0.0002	.1
2035	PFVVSSS	0.0681	146	0.0022	2
2037	FFFJV	0.1767	403	0.0028	5
2038	CFPFVFS	0.2674	1020	0.0000	.1
2041	Flour/OGMP	0.0108	24	0.0020	4
2043	Cereal Bkfst Food	0.2649	670	0.0000	0
2044	Rice Milling	0.0185	9	0.0187	8
2045	PFM	0.0274	30	0.0018	.4
2046	Wet Corn Milling	0.0152	19	0.0050	.2
2047	Dog-Cat FD	0.0528	57	0.0000	14
2048	PFFI	0.0371	135	0.0000	.4
2051	Bread/OBP	0.1712	1294	0.0002	0
2052	Cookies-Crackers	0.2186	651	0.0000	0
2061	Cane Sugar/ERF	0.0175	9	0.0002	.1
2062	Cane Sugar RF	0.0920	179	0.0000	.01
2063	Beet Sugar	0.0183	17	0.0004	.2
2064	Candy/OC	0.2150	838	0.0001	.2
2066	Chocolate/CP	0.0385	49	0.0002	2
2067	Chewing Gum	0.0330	20	0.0000	.03
2074	Cottonseed/OM	0.0171	7	0.0004	.2
2075	Soybean OM	0.0439	162	0.0001	3
2076	VOM/ECCS	0.0032	4	0.0029	4
2077	Animal-Marine FO	0.0202	5	0.0002	.5
2079	STMOEONEC	0.0049	110	0.0002	.3
2082	Malt Beverages	0.0039	121	0.0008	3.4
2083	Malt	0.0032	.7	0.0172	.2
2084	WBBS	0.0129	9	0.0002	.2
2085	Distilled BL	0.0390	40	0.0024	2
2086	BCSDCW	0.5739	5015	0.0013	4
2087	FEFS/NEC	0.0836	93	0.0005	.4
2091	CCFS	0.1373	133	0.0003	.1
2092	PFFS	0.4078	888	0.0000	0
2095	Roasted Coffee	0.1166	413	0.0158	42
2097	Manufactured Ice	0.0205	4	0.0024	.2
2098	MSVN	0.0659	41	0.0038	1
2099	Food Prep./NEC	0.2827	2045	0.0089	32