NEWP

W.P.-15

NE-165

PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE

Testing for Oligopoly and Oligopsony Power

by

Azzeddine Azzam and Emilio Pagoulatos

WP-15 September 1989

WORKING PAPER SERIES

A Joint USDA Land Grant University Research Project

Testing for Oligopoly and Oligopsony Power

by

Azzeddine Azzam and Emilio Pagoulatos

WP-15 September 1989

The results reported are based upon an Experiment Station project concerned with the functioning of the Food Marketing System. The paper has been written specifically as our contribution to the NE-165 project.

The authors are Assistant Professor, Department of Agricultural Economics, University of Nebraska-Lincoln and Professor and Head, Department of Agricultural Economics and Rural Sociology, University of Connecticut.

TESTING FOR OLIGOPOLY AND OLIGOPSONY POWER

SUMMARY

This paper extends the conjectural approach in industrial organization to the analysis of imperfections in output and factor markets simultaneously. Starting from the specification of a production function, the econometric analysis is based on the formulation and estimation of a simultaneous equation model consisting of a production function, first order conditions associated with factor employment, and two conjectural elasticities to parametrize the industry's oligopoly and oligopsony equilibria. As an example, we provide an application to the U.S. meat packing industry. Our results suggest that the industry excercised market power in both the output (meat) market and the factor (live animals) market.

1. INTRODUCTION

Recent studies in applied industrial organization have popularized the use of conjectural elasticity models to study market power. Several studies have estimated such models (See Geroski (1988) and Bresnahan (1987) for a survey) but virtually all applications consider market power in the output market only. Only one (Śchroeter, 1988) has considered an industry in which market power is exercised in both the output and the input markets. From the standpoint of econometric estimation, inference of market power from an oligopoly/oligopsony model or an oligopoly model involves three sets of unknown parameters: costs, demand and firm or industry conduct. So, construction of a model with imperfections in both the input and output markets would involve a simple adaptation of an oligopoly model [such as Appelbaum's (1982), for example]. The problem, however, is that such adaptation is possible only if certain restrictions are imposed on the firm's cost function.

Since the cost function has as arguments the price(s) of the input(s), deriving an expression for the conjectural elasticity in the factor market is not straightforward unless the production technology is restricted to be of fixed proportions between the output and the oligopsonistically purchased input. Consequently, the conjectural elasticities in the imperfect output and input markets turn out to be identical since the oligopsonized input and output can be represented by the same variable in the profit function (see Schroeter, 1988). The problem with this formulation is that identical conduct in the two markets is not an implication of oligopoly/oligopsony theory but a result of the imposed technology.

The purpose of this paper is to propose an alternative empirical model to test for market power in both input and output markets and apply it to the U.S. meat packing industry.[1] Unlike Schroeter's model, the model in this paper is developed without imposing identical market power on the buying and the selling side of the market. To do so, we use a production function approach which a) allows all inputs to be used in variable proportions and b) allows the derivation of market-specific conjectural elasticities. This enables us to provide a parametric test for the equality of market power on both sides of the market. Like Schroeter's study, the framework in this paper is applied to aggregate industry behavior, since detailed firm data on the inputs required for estimation are not available. [2].

In the next section, the theoretical model is presented. The estimating model and empirical results are presented in the third section. Based on published testimonies to various congressional committes and previous research, our prior notion is that the U.S. meat packing industry exerts some degree of market power. Moreover, we suspect that market power exercised by the industry is different in the two markets and that it is likely be higher in the input (livestock) markets. In contrast to the meat market, which is national in scope, the market for slaughter animals is generally within a few hundered mile radius (Monfort of Colorado v. Cargill). Our empirical results confirm these notions. The hypothesis of identical market power in the two markets is rejected. The average degrees of oligopoly and oligopsony power were found to be statistically significant.

2. THEORETICAL FRAMEWORK

Consider the U.S. meat packing industry in which N firms produce a homogeneous output using M inputs. Let the jth firm's technology be defined by the production process f

$$q_j = f(x_{1j}, x_{2j}, ..., x_{Mj}) \tag{1}$$

where q_j is output produced (meat), x_{1j} is the farm input (livestock), and x_{kj}, (indexed k=2,...,M) represent nonfarm inputs. Furthermore, assume each firm exercises some market power in purchasing the farm input x_{1j} and in selling its output q_j but is a price taker in the market for other inputs.

Let the (wholesale) market inverse demand curve facing the industry in its output market be given by

$$P = g(Q), \tag{2}$$

where P and $Q = \sum_{j=1}^{N} q_j$ are market meat price and total industry output, respectively. The market inverse supply function for the agricultural input is given by

$$w_1 = h(X_1), \tag{3}$$

where w_1 and $X_1 = \sum_{j=1}^{N} x_{1j}$ are market livestock price and total industry livestock input, respectively. Denoting the price of nonfarm inputs by $w_2, ..., w_M$, and assuming each firm is a profit maximizer, the problem for the jth firm is to choose x_{kj}, (indexed k=1,2,...,M) so as to maximize profits Π_j

$$\Pi_j = Pq_j - \sum_{k=1}^{M} w_k x_{kj} \qquad \text{for j=1,2,...,N,} \tag{4}$$

subject to (2) and (3). The first order conditions corresponding to this profit maximization problem are given by

$$\frac{\partial \Pi_j}{\partial x_{1j}} = P(1 - \frac{\theta_j}{\eta}) f_{x_1} - w_1(1 + \frac{\phi_j}{\epsilon}) = 0 \tag{5}$$

$$\frac{\partial \Pi_j}{\partial x_k} = P(1 - \frac{\theta_j}{\eta}) f_{x_k} - w_k = 0 \tag{6}$$

or

$$\frac{w_1}{P} = (1 - \frac{\theta_j}{\eta}) f_{x_1} - \frac{w_1}{P}\frac{\phi_j}{\epsilon}, \tag{7}$$

$$\frac{w_k}{P} = (1 - \frac{\theta_j}{\eta}) f_{x_k} \qquad \text{for k=2,...,M} \tag{8}$$

where $\eta = \frac{\partial Q}{\partial P}\frac{P}{Q}$ is the absolute value of the price elasticity of output demand;

$\epsilon = \frac{\partial X_1}{\partial w_1}\frac{w_1}{X_1}$ is the market price elasticity of farm input supply;

$\theta_j = \frac{\partial Q}{\partial q_j}\frac{q_j}{Q}$ is the jth firm's conjectural elasticity in the output market;

$\phi_j = \frac{\partial X_1}{\partial x_{1j}}\frac{x_{1j}}{X_1}$ is the jth firm's conjectural elasticity in the agricultural input market;

and $f_{x_k} = \frac{\partial q_j}{\partial x_{kj}}$ is the marginal product of the kth input.

In theory, the conjectural elasticities, θ_j and ϕ_j, as shown in (7) and (8), provide useful benchmarks for testing for price-taking behavior or degree of competitiveness (Appelbaum, 1982). Assuming positive marginal products, if both θ_j and ϕ_j are equal to 0, we have the perfectly competitive case where each firm equates the marginal product of each input to its real price. In the extreme case where both θ_j and ϕ_j are equal to 1, we obtain the monopoly and monopsony case for the output and the farm input, respectively. Other combinations of market structures can be identified: monopoly in input markets and perfect competition in output markets ($\theta_j = 0$ and $\phi_j = 1$) or vice versa. Alternatively, one can identify the location of the firm on the continuum between the two poles of market structure as θ_j and ϕ_j can take on individual values between zero and one. The ratio of the conjectural elasticities to the demand and supply elasticities measure the degree of market power in the output and input market, respectively.

In practice, the absence panel data on firm level output and employment levels of factors of production means that the system embodied in (7) and (8) cannot be readily estimated. This limitation leads us to consider the problem on an aggregate level. In doing so, however, certain additional assumptions must be maintained to make the preceding analysis applicable to the behavior of the industry as a whole.

The first assumption is that marginal products are constant and identical across firms in equilibirum. This implies that any deviation from price taking behavior can be accounted for by the respective firm's conduct as reflected by the conjectural elasticities. Absence of firm level data, however, prohibits estimation of conjectural elasticities for individual firms. Hence, a procedure is needed to aggregate the individual firm's conjectural elasticities. One procedure originally adopted by Appelbaum (1982) is to assert that all conjectural elasticities are identical across firms. The problem with this assertion is that it is not an implication of the theory as there is nothing in the logic of oligopoly theory to suggest all firms to have the same conduct (Bresnahan (1987), p.33). A more tenable alternative is to use weighted averages of individual conjectural elasticities, where the weights are each firm's share in total input our output (also adopted by Cowling and Waterson, 1976). For our purposes, this is accomplished by multiplying equations (7) and (8) by q_j, summing over firms, and dividing the result by total industry output Q. The aggregate analogue of the optimality conditions, (7) and (8), may now be written as follows:

$$\frac{w_1}{P} = (1 - \frac{\Theta}{\eta}) f_{X_1} - \frac{w_1}{P} \frac{\Phi}{\epsilon}, \tag{9}$$

$$\frac{w_k}{P} = (1 - \frac{\Theta}{\eta}) f_{X_k} \qquad \text{for k=2,...,M} \tag{10}$$

where $\Theta = \sum_j^N (\frac{q_j}{Q})\theta_j$, and $\Phi = \sum_j^N (\frac{q_j}{Q})\phi_j$. The ratios $\frac{\Theta}{\eta}$ and $\frac{\Phi}{\epsilon}$ represent industry wide indices of market power in the output and input markets, respectively. the hypothesis of equal market power in the two markets can be stated as $\Theta/\eta = \Phi/\epsilon$. If the hypothesis is accepted then a test of price taking behavior will entail testing the joint hypothesis $\Theta/\eta = \Phi/\epsilon = 0$. If rejected, it is sufficient to test the equality of the respective indices of market power to zero. The next section outlines the empirical model.

3. EMPIRICAL MODEL AND RESULTS

In order to estimate the model of industry oligopoly/oligopsony behavior developed in the previous section (equations 9 and 10), and test the hypothesis of price taking behavior in the meat packing industy, we need to select a functional form for the production function. It is desirable that the form does not impose any *a priori* constraints on the production characteristics in the industry. One function suitable for our purposes is the transcendental logarithmic production function (Christensen, Jorgensen and Lau, 1971).

$$\ln Q = \beta_0 + \sum_{k=1}^{4} \beta_k \ln X_k + 1/2 \sum_{k=1}^{4}\sum_{j=1}^{4} \beta_{kj} \ln X_k \ln X_j \tag{11}$$

where Q = red meat production. We further assume that in addition to the livestock input (X_1), there are three competitively priced inputs in the meat packing industry: labor (X_2), capital (X_3), and non-livestock material (X_4).

From equation (11), the marginal product for the kth input is

$$f_{X_k} = [\beta_k + \sum_{j=1}^{4} \beta_{kj} \ln X_j](\frac{Q}{x_k}), \qquad \text{for k=1,2,3,4.} \tag{12}$$

Substituting (12) into (9) and (10) and rearranging leads to the following system of k+1 equations

$$\ln Q = \beta_0 + \sum_{k=1}^{4} \beta_k \ln X_k + 1/2 \sum_{k=1}^{4}\sum_{j=1}^{4} \beta_{kj} \ln X_k \ln X_j$$

$$S_1 = \{\frac{1+M}{1+L}\}\{\beta_1 + \sum_{j=1}^{4} \beta_{1j} \ln X_j\}$$

$$S_2 = \{1+M\}\{\beta_2 + \sum_{j=1}^{4} \beta_{2j} \ln X_j\} \qquad (13)$$

$$S_3 = \{1+M\}\{\beta_3 + \sum_{j=1}^{4} \beta_{3j} \ln X_j\}$$

$$S_4 = \{1+M\}\{\beta_4 + \sum_{j=1}^{4} \beta_{4j} \ln X_j\}$$

where $S_k = \frac{w_k X_k}{PQ}$ (for k=1,2,3,4) is the share equation for the kth input, $M = \frac{\Theta}{\eta}$, and $L = \frac{\Phi}{\epsilon}$.

The data used in the estimation of the system of equations (13) are annual aggregate time series for the United States meat packing industry from 1959 through 1982[3]. The variable definitions and sources are as follows:

Q = Total U.S. commercial red meat (beef, pork, sheep and lamb) production (million lbs. carcass weight) obtained from various issues of *Livestock and Meat Statistics.*

$S_1 = \frac{w_1 X_1}{PQ}$ is the cost of livestock input relative to the value of shipment constructed from *Census of Manufacturers*, various issues. The proportion of material cost attributed to the livestock input is published by the Census Bureau every five years only. For the periods between the census years, we assumed the proportion of material cost that is livestock to hold for the years between the current and the previous census.

$S_2 = \frac{w_2 X_2}{PQ}$ is total labor wages in millions of dollars relative to the value of shipments, Sources: *Census of Manufacturers*, and *Employment and Earnings*. Labor wages were calculated as the product of the total hours worked by production workers X_2 and the production worker average hourly earnings w_2 for SIC2011 (meat packing plants).

$S_3 = \frac{w_3 X_3}{PQ}$ is the value of capital input relative the value of shipments obtained from the *Corporation Source Book of Statistics of Income.* The value of the capital input and capital cost were calculated following the procedure outlined in Gollop and Roberts (1979). The capital input (X_3) is the sum of net depreciable and depletable assets, land and inventories. The cost of capital (w_3) was computed by dividing the sum of interest, depreciation, and depletion expenses by (X_3).

$S_4 = \frac{w_4 X_4}{PQ}$ is the cost of non-livestock material input relative to the value of shipments. The non-livestock material input (X_4) was computed as the quotient formed by dividing the cost of non-livestock material by the price index of intermediate inputs in manufacturing (w_4) published in *Statistical Abstracts*, various issues.

For empirical implementation, we assume that the production function and the share equations are stochastic due to technical errors and errors in optimization, respectively. The errors are assumed to be additive and jointly normally distributed with zero mean and constant variance-covariance matrix. Since output and all inputs in the model are endogenous, the Iterative Nonlinear Three Stage Least squares (IT3SLS) technique was used to avoid simultaneity bias[4]. Finally, since the estimation of the conjectural elasticities requires estimates of the demand and supply elasticities, we followed similar empirical studies (Gelfand and Spiller, 1987; Gollop and Roberts, 1979; Roberts,1984), and introduced them exogenously [5].

The parameter estimates of the production function and their respective standard errors are presented in Table 1. Of the fifteen production function parameters, only the parameter b_{12} was not statistically significant at the 5 percent level. The estimated average conjectural elasticities in the output and input market were .176 and .109, respectively. The estimated measures for the indices of oligopoly and oligopsony power were .461 and .681. The hypothesis of identical indices of market power in the product and input (livestock) market is rejected at the 95 percent level[6]. Examination of the individual indices suggest that market power is indeed higher in the livestock procurement market.

Table 1. Estimated Parameters of the Full Model

(standard errors in parentheses)

Translog production function parameters	Estimate	
β_0	-.014	(.006)
β_1	.804	(.055)
β_2	.038	(.005)
β_3	.052	(.006)
β_4	.128	(.016)
β_{11}	.199	(.057)
β_{22}	-.045	(.015)
β_{33}	.029	(.005)
β_{44}	.119	(.020)
β_{12}	.010	(.009)
β_{13}	.018	(.008)
β_{14}	-.127	(.021)
β_{23}	.094	(.018)
β_{24}	-.009	(.004)
β_{34}	-.013	(.004)
Conjectural Elasticity Parameters		
Output market:		
Θ	.176	(.073)
Input market:		
Φ	.109	(.041)
Indices of Market Power		
Output market:		
L	.416	(.031)[a]
Input market:		
M	.681	(.006)[a]

[a]Standard errors were calculated with elasticities assumed fixed.

4. CONCLUSIONS

The purpose of this paper was to extend the traditional conjectural approach to the analysis of imperfections in output and factor markets simultaneously. Starting from the specification of a production function, the econometric analysis is based on the formulation and estimation of a simultaneous equation model consisting of a production function, first order conditions associated with factor employment, and two conjectural elasticities to parametrize the industry's oligopoly and oligopsony equilibria. Our results suggest that, for the sample period considered, the U.S. meat packing industry was not a price-taker in neither the output (meat) market or the factor (livestock) market.

FOOTNOTES

[1]The U.S. meat packing industry has often been at the center of controversy over conditions of competition in both its livestock procurement and wholesale meat markets (Nicholls; Yeager). Recent concern about the potential exercise of oligopsony and oligopoly power by meat packers has grown out of a reversal that began in the 1970s of an earlier trend toward deconcentration in the market. The four largest beef packers increased their share of the national market from 29 percent in 1972 to 45 percent in 1982. The four largest firms in hog slaughtering and processing increased their national share from 32 percent in 1972 to 36 percent in 1982 (U.S. House of Repres., 1980). The trend toward fewer and larger firms resulting from mergers and acquisitions has continued since 1982, suggesting the possibility that packers may exert market power over both cattle buying and meat selling prices.

[2] The paper by Schroeter (1988) used aggregate data for the beef packing industry. Only one share equation for the labor input was considered. As a consquence, the parameter estimates did not take into account the cross-equation restrictions implied by the theory. In this paper, we consider four inputs: live animals, labor, capital and non-livestock material inputs.

[3] The sample period was dictated by data availability. The year 1982 is the most recent

year for which census data is available.

[4] The estimation approach was also adopted in a similar study by Gollop and Roberts (1979). A discussion of statistical inference from nonlinear estimation procedure is provided by Gallant (1987). The exogenous variables used were the meatpacking wage rate, the price of capital, the price of non-livestock inputs, a time trend, the price of poultry, the number of animal units as of January 1st, and per capita income.

[5] The literature is divided on the issue of introducing elasticities into the estimating model. Some authors (Applebaum, 1982; Lopez, 1984) estimated demand equations jointly with the full system. Others (Gollop and Roberts, 1979; Roberts, 1984; Gelfant and Spiller, 1987) obtained elasticity estimates from extraneous sources. In this study we attempted to estimate the demand and supply elasticities jointly with the full model by specifying a wholesale demand function for meat and a supply function of live cattle. Unfortunately, joint estimation resulted in a Lerner index greater than one, which is inconsistent with theory. To deal with the problem, we estimated the supply and demand functions separately from the full system and subsequently used the elasticity point estimates to be able to estimate the conjectural elasticities. Per capita demand for output (Q) was specified as a function of the price index of total read meat, the price index of poultry (source: Agricultural Statistics, various issues), and per capita disposable income (source: Economic

Report to the president, various issues). Supply of livestock (in millions of pounds) was specified as a function of the index or prices received by farmers for meat animals, the price index of prices received for feed grains, and an index of the inventory of meat animal units (source: Agricultural Statistics, various issues).

[6] The calculated χ^2 statistic is 5.21. The critical value is 3.84.

REFERENCES

Appelbaum, E (1982), 'The estimation of the degree of oligopoly power', *Journal of Econometrics*, 19,287-299.

Bresnahan, T. F. (1987), 'Empirical studies of industries with market power', Stanford University, Center of Economic Policy Research, Publication No. 95.

Bureau of the Census , *Census of Manufacturers*, U.S.G.P.O., Washington, D. C., various issues.

Christensen, L. R., D.W. Jorgenson and L. J. Lau (1971), 'Conjugate duality and the transcendental logarithmic production function', *Econometrica*, 39,255-256.

Council of Economic Advisors , *Economic Report to the President*, U.S. Government Printing Office, Washington, D. C., various issues.

Cowling K. and M. Waterson (1976),'Price-post margins and market structure', *Economica*, 43,267-274.

Gallant, R. A. (1987), *Nonlinear Statistical Models,* Wiley, New York.

Gelfant, M. D., and P. T. Spiller (1987),'Entry barriers and multiproduct oligopolies:

do they forbear or spoil?', *International Journal of Industrial Organization*, 5,101-113.

Geroski, P. A. , 'In pursuit of monopoly power: recent quantitative work in industrial economics', *Journal of Applied Econometrics*, 3, 107-124.

Gollop, F. and M. Roberts (1979),'Firm interdependence in oligopolistic markets', *Journal of Econometrics*, 10,313-331.

Lopez, R. (1984),'Measuring oligopoly power and production responses of the canadian food processing industry', *Journal of Agricultural Economics*, 35,219-230.

Monfort of Colorado v. Cargill Inc. and Excel Corp. (1983), U.S. District Court (Colorado), Civil Action 83-F-1318, Opinion and Order.

Nicholls, W. H. (1941), *Imperfect competition within agricultural industries*, Iowa State College Press, Ames.

Roberts, M. J. (1984), 'Testing oligopolistic behavior', *International Journal of Industrial Organization*, 2,367-383.

Schroeter, John R. (1988), 'Estimating the degree of market power in the beef packing industry', *Review of Economics and Statistics*, 70,158-162.

U.S. Department of Agriculture , *Livestock and Meat Statistics*, Economic Research Service, various issues.

U.S. Department of Agriculture , *Agricultural Statistics*, U.S. Government Printing Office, Washington, D.C., various issues.

U.S. Department of Commerce , *Statistical Abstracts*, Bureau of the Census, U.S. Government Printing Office, Washington, D. C., various issues.

U.S. Department of Labor , *Employment and Earnings*, Bureau of Labor Statistics, U.S. Government Printing Office, Washington, D. C., various issues.

U.S. Department of the Treasury , *Corporation Source Book of Statistics of Income*, Internal Revenue Service, Washington, D. C., annual issues from 1958 to 1982.

U.S. House of Representatives Committee on Small Business (1980), *Small Business Problems in the Marketing of Meat and other Commodities*, U.S. 96th Congress, 2nd Session.

Yeager, M. (1981), *Competition and Regulation: The Development of Oligopoly in the Meat packing Industry*, JAI press, Greenwich, CT.

NE-165

PRIVATE STRATEGIES, PUBLIC POLICIES & FOOD SYSTEM PERFORMANCE

Working Paper Series

Purpose: The NE-165 Working Paper Series provides access to and facilitates research on food and agricultural marketing questions. It is intended to be a publication vehicle for interim and completed research efforts of high quality. A working paper can take many forms. It may be a paper that was delivered at a conference or symposium but not published. It may be a research report that ultimately appears in full or abbreviated form as a journal article or chapter in a book. Using the working paper series enables a researcher to distribute the report more quickly and in more extensive detail to key research users. A working paper may also be an end product in itself, for example, papers that collate data, report descriptive results, explore new research methodologies, or stimulate thought on research questions.

Procedures: Working papers may address any issues in the food and agricultural marketing area as described in the NE-165: Private Strategies, Public Policy and Food System Performance, project statement. This research agenda is available from Professor Ronald Cotterill, Executive Director of NE-165 at the address given below. A prospective working paper should be forwarded to the Executive Director who will coordinate a review of the paper by two research peers. Alternatively authors may submit two independent peer reviews with their paper. Based upon independent reviewer comments the Executive Director may accept, accept with revisions, or reject the submission. If accepted the Executive Director will issue working paper covers, and a mailing list to the author who shall have responsibility for preparing and distributing copies to all persons and organizations on the mailing list. Additional copies of working papers are available from the author or from the office of the Executive Director at The University of Connecticut.

Professor Ronald W. Cotterill, Executive Director NE-165
Department of Agricultural Economics and Rural Sociology
Box U-21
The University of Connecticut
Storrs, Connecticut 06268