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Testing for Switching Market Conduct

by

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In a theoretical paper that has become a standard reference in the new empirical industrial organization literature, Bresnahan showed that market conduct in a homogeneous oligopoly can be determined from a simple industry supply and demand model. The starting point of Bresnahan's procedure is the familiar equality of marginal cost (MC) to the marginal revenue function as perceived by the firm, $P + \theta g(Q, Y, \alpha)$, where P is price, Q is quantity, Y a demand shifter, α parameters of the demand function to be estimated, and θ is a measure of market conduct or index of market power.[1] If $\theta = 0$, then $P = MC$ and competition is present. If $\theta = 1$, then $P > MC$ and the industry is a perfect cartel. Values of θ between zero and one also generate $P > MC$ but correspond to an oligopoly solution. The econometric problem is to identify θ when estimating industry demand and supply simultaneously. Bresnahan demonstrated that this could be accomplished by shifting as well as rotating the demand curve.

The simplicity and modest data requirements of Bresnahan's procedure prompted several industry studies (Alexander, Baker, Shaffer, Sjostrom). However, the estimated measure of conduct in the studies is only an average measure over the sample period. Little is known as to how conduct is affected by legal, institutional or economic changes.

Two studies considered how legal and institutional changes may have affected conduct: one by Lopez on the Haitian coffee market, the other by Buschena and Perloff on the Philippine coconut export market. Both studies assume the response of conduct is immediate and the points of change are known with certainty. A more plausible response by an industry is a response that is perhaps more gradual and where the points of change are not known. An example of this would be a change in industry conduct in an atmosphere of lax or vigorous enforcement of antitrust laws.

A primary objective of this paper is to combine Breshanhan's procedure with a switching regression technique which identifies the starting and ending points for a change in

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[1]Shaffer has shown that θ is algebraically equivalent to the conjectural variation. Conjectural variations are often subject to several interpretations ranging from an index of market power to deviations of prices and quantities from their shadow levels. In this paper, θ is simply an intuitive summary of a measure of market conduct as in Brander and Zhang.

industry conduct. For the intended application of the model, a second important objective is to reformulate Bresnahan's procedure to estimate industry conduct in factor rather than output markets.

For an application, we consider the U.S. beef slaughter industry. The industry has a long history of controversy over conditions of competition in its purchases of live cattle. In 1890, four firms controlled about 89 percent of all the cattle slaughter in Chicago (Yeager), the country's dominant slaughter center a hundred years ago. The level of concentration in the industry played a prominent role in the passage of the America's first antimonopoly law, the 1890 Sherman Antitrust Act (Libecap). It has also played a role in the passage of the Packers and Stockyard Act. Enacted by Congress in 1921, the Act resulted in the creation of the Packers and Stockyards Administration to oversee livestock market competitiveness (General Accounting Office). The four firm concentration ratio in the industry did not exceed thirty percent between 1921 and 1977. Between 1977 and 1988 the ratio increased from 29.1 to 69.7 (Marion and Kim) raising concern once again about oligopsonistic conduct in the industry. Examples of recent empirical work addressing that concern include Schroeter, and Schroeter and Azzam.

The Theoretical Model

Let P be the output (beef) price and w be the input price for the material input (live cattle). Assuming that the production relationship between output and input is one of fixed proportions,[2] we can denote both the output and the material input by the same variable Q_B and write the following output demand and material input supply functions:

$$P = F(Q_B, \mathbf{y}) + \epsilon \tag{1}$$

$$w = G(Q_B, \mathbf{z}) + \nu \tag{2}$$

where $\mathbf{y}$ and $\mathbf{z}$ are, respectively, vectors of demand and supply shifters. Random fluctuations in demand and supply are represented by ϵ and ν, respectively. The supply function (2) defines the marginal expenditure (ME) function (3), where G_q stands for the slope of the supply function.

$$ME = G(Q_B, \mathbf{z}) + Q_B G_q(Q_B, \mathbf{z}) + \nu \tag{3}$$

[2]This is a reasonable assumption in food processing when a mass of raw material input, such as cattle, is transformed into carcasses or retail cuts.

Denoting the marginal processing costs of beef by $c(Q_B, W)$, where W is a cost shifter, and assuming perfect competition in the output market,[3] equilibrium in the material input market requires

$$F(Q_B, \mathbf{y}) + \epsilon - c(Q_B, W) = G(Q_B, \mathbf{z}) + Q_B G_q(Q_B, \mathbf{z}) + \nu \tag{4}$$

or, equivalently

$$h(Q_B, \mathbf{y}, W) + \epsilon = G(Q_B, \mathbf{z}) + Q_B G_q(Q_B, \mathbf{z}) + \nu \tag{5}$$

where $h(Q_B, \mathbf{y}, W)$ is the marginal value product of cattle net of processing cost. Solving for w and substituting from (3) gives the derived demand relation

$$w = -\theta(ME - w) + h(Q_B, \mathbf{y}, W) + \epsilon \tag{6}$$

where θ is a measure of market conduct in the factor market. If θ is zero, then the price of factor is equal to its net marginal value product. A monopsony cartel will be characterized by $\theta = 1$. Values of θ between 0 and 1 characterize alternative oligopsony solutions.

For empirical implementation, assume the beef supply function takes the form

$$Q_B = \alpha_o + \alpha_1 w + \alpha_2 F + \alpha_4 C + \nu \tag{7}$$

and the (derived) demand function

$$h(Q_B, \mathbf{y}, W) = \beta_o + \beta_1 Q_B + \beta_2 Q_P + \beta_3 Q_C + \beta_4 I + \beta_5 W + \varepsilon \tag{8}$$

where, w is the price of cattle, F is the price of feed, C is cattle inventory, I is income, W is the meat-processing wage, and Q_P and Q_C are the quantities of pork and poultry, respectively. The parameters to be estimated are denoted by α and β. The error terms are ν and ε.

Given the supply function (7), the implied marginal expenditure function (equation 3) becomes

$$ME = w + \frac{Q_B}{\alpha_1} \tag{9}$$

Making use of (9), the derived demand relation (6) may now be rewritten as

$$w = \beta_o - \rho Q_B + \beta_2 Q_P + \beta_3 Q_C + \beta_4 I + \beta_5 W + \varepsilon \tag{10}$$

[3]Since oligopsony conduct in the industry seems to be of more concern that oligopoly, the model proceeds accordingly.

where $\rho = \beta_1 + \theta/\alpha_1$.

Since the derived demand relations (10) and (8) are observationally equivalent, it is not possible to disentangle the measure of market conduct θ even if an estimate of α_1 is available. To identify θ, we need a rotation as well as a shift in the supply function. To rotate supply function an interaction term between the price of cattle and the price of feed is added.[4] The new supply function is

$$Q_B = \alpha_o + \alpha_1 w + \alpha_2 F + \alpha_3 C + \alpha_4 w.F + \nu \tag{11}$$

this implies the derived demand relation

$$w = \beta_o + \theta Q_B^* + \beta_1 Q_B + \beta_2 Q_P + \beta_3 Q_C + \beta_4 I + \beta_5 W + \varepsilon \tag{12}$$

where

$$Q_B^* = -Q_B/(\alpha_1 + \alpha_4 F). \tag{13}$$

Hence, the coefficient of Q_B^* is the measure of market conduct. Equations (11) and (12) can be estimated simultaneously using nonlinear estimation techniques. For our purposes, we allow θ to vary over the sample period rather than restrict it to be constant. The starting and ending points which mark periods of structural change in θ are also identified. To do so, we implement a technique suggest by Ohtani *et al.* The technique, as shall be outlined below, identifies both the starting and ending points for a change in market conduct.

The Switching Technique

In general, the switching regression model is specified as as

$$y_t = \mathbf{x}_t'(\beta_t + \lambda_t \delta) + \varepsilon_t, \qquad \text{t=1,2,..., T.} \tag{14}$$

where y_t is the t^{th} observation on the dependent variable, $\mathbf{x}_t'$ is a 1×k vector of the t^{th} observations on the explanatory variables, β and δ are k×1 vector of coefficients, λ_t is a transition path of coefficients, and ε_t is the t^{th} error term which is normally distributed and independently distributed with mean 0 and variance σ^2.

[4]Lau defined necessary and sufficient conditions for identifying the index of industry competitiveness from industry price and output data and other exogenous variables. In the case of oligopoly, this condition requires that the inverse demand function be separable in the exogenous variables. In the oligopsony case, this condition is satisfied by incorporating the interaction term in the supply function. Lau's proof is easily modified to apply to the specification of the inverse supply function.

The coefficients are assumed to shift from β to δ along a transition path λ_t defined by

$$\begin{aligned} \lambda_t &= 0 \qquad \text{for } t \leq t_1^* \\ &= \alpha_0 + \alpha_t t + \alpha_2 t^2 + \cdots + \alpha_n t^n \qquad \text{for } t_1^* < t < t_2^* \\ &= 1 \quad \text{for } t \geq t_2^* \end{aligned} \tag{15}$$

where t_1^* is an end-point of the first regime and t_2^* is a starting point of the second regime.

Ohtani *et al.* demonstrate that maximum likelihood estimates of β, δ, and σ^2 can be obtained using a sequence of ordinary least squares (OLS) regressions. Each OLS regression defines the value of the concentrated likelihood function, L_{max}.

The order of the polynomial in t for the transition path is chosen to minimize the Schwarz Criterion defined as $SC(n) = -2L_{max}(t_1^*, t_2^*, a) + 2n$. Maximum likelihood estimates of the end-point of the first regime t_1^* and the starting point of the second regime t_2^* along the coefficients of the transition path a are obtained by a grid search over the region (t_1^*, t_2^*, a) for given transition path.

Empirical Model and Results

Using (14) and adding a time subscript to (11) and (12), the new estimating model becomes

$$Q_{Bt} = \alpha_o + \alpha_1 w_t + \alpha_2 F_t + \alpha_3 C_t + \alpha_4 w_t.F_t + \nu_t \tag{16}$$

$$w_t = \beta_o + (\theta + \lambda_t \delta) Q_{Bt}^* + \beta_1 Q_{Bt} + \beta_2 Q_{Pt} + \beta_3 Q_{Ct} + \beta_4 I_t + \beta_5 W_t + \varepsilon_t \tag{17}$$

Precise definition of the variables in the model are as follows. The variable w_t is the price of slaughter steers, choice grade, Omaha (\$/cwt); F_t is the price of No.2 yellow corn (\$/bushel), C_t is cattle inventory, January 1 (mil. head), W_t is production worker average hourly earning in SIC 2011 (\$/hour); I_t is nominal per-capita disposable income; Q_{Bt}, Q_{Pt}, and Q_{Ct} are, respectively, commercial production of beef, pork, and chicken (mil. lbs). The model's variables were collected from government publications, *Livestock and Poultry Situation, Livestock and Meat Statistics, Employment and Earnings,*, and *Agricultural Outlook.* The data for estimating the model are aggregate yearly time series from 1960 through 1987.

Following Thurman, a Wu-Hausman test was applied to the model in equation (16) to test the endogeneity of the price of slaughter steers (w_t). If the price is predetermined, the ordinary least squares yields best linear unbiased estimates, denoted by $\hat{\alpha}$. If prices are endogenous in the supply specification, instrumental variable estimates, denoted by $\tilde{\alpha}$, are consistent, while ordinary least squares estimates are biased and inconsistent.

A test statistic for the endogeneity of the slaughter steer price is

$$T = (\hat{\alpha} - \tilde{\alpha})\ [\hat{V}(q)]^{-1}(\hat{\alpha} - \tilde{\alpha}) \tag{18}$$

where $\hat{V}(q)$ is a consistent estimate of the variance-covariance matrix under the null hypothesis and T is asymptotically distributed as χ^2_1. Instrumental variable estimates were obtained using two-stage least squares. The Wu-Hausman test resulted in a test statistic of 0.08, well below χ^2_1 critical value of 3.84. The test fails to reject the null hypothesis that the prices of slaughter steers are predetermined, indicating that ordinary least squares estimation provides unbiased and consistent estimates. Hence, the quantity dependent specification is an appropriate model to use in developing θ.

The parameters of the beef supply equation which are corrected for first-order autocorrelation are presented in Table 1. The estimated coefficient for the price of slaughter steers is positive and significant, consistent with a supply function. Though the positive sign of the price of feed is not consistent with a supply function, it is statistically not different from zero. Increases in the cattle inventory have, as expected, a positive and statistically significant impact on beef supply.

The estimates of α_1 and α_4 from Table 1 are used to generate the regressor Q^*_B according to (13). Recall the coefficient on Q^*_B in the derived demand equation (12), which measures market conduct, is allowed to shift along a flexible transition path defined by a polynomial function of time. Maximum likelihood estimates of (12) were obtained using nonlinear least squares techniques. The order of the polynomial in (λ) and the ending point of the firm regime (t^*_1) and the starting point of the second regime (t^*_2) were selected based on the maximum likelihood estimates which yielded the minimum value of the Schwarz criterion (SC). Following Ohtani *et al.*, polynomial transition paths of order 1 through 3 were examined and the optimal order of the polynomial in λ_t was n = 3. Parameter estimates of the derived demand equation are presented in Table 2.

The estimation results for variables other than those dealing with conduct are mixed. Both the quantity of beef Q_B and income I have the expected signs and are statistically different from zero. As expected, an increase in the quantity of pork shifts the derived demand to the left. However, the coefficient estimate is not different from zero. Surprisingly, poultry shows strong complementarity with beef. Increases in the meat-packing wage leads to higher processing costs and shifts the derived demand for slaughter cattle to the left. The results indicate the opposite. A plausible explanation for the result is that the wage rate in all meat-packing may not be a good proxy for wages in the beef packing subsector.

Interpreting the Measure of Market Conduct

The coefficient on Q^*_{Bt} measures market conduct. A test that the measure of market power is constant and does not shift over the sample period is first developed. If the δ coefficients from (17) are zero, the index of market power is constant over the sample period. This hypothesis is rejected since each of the three δ_t coefficients is significantly different from zero.

Figure 1 shows the changes θ over the sample period and identifies two distinct regimes of conduct. The first regime started in 1960 and ended in 1977. The point estimate of θ during that regime was constant at .0092. Although the magnitude of the index is small, it differs significantly from zero (the standard error is .0007), implying noncompetitive market conduct.

After the first regime, a transition period started in in 1978 and ended in 1989, during which θ reached a peak value of .031 in 1979. The years between 1982 through 1987 mark a second separate regime for industry conduct. By 1982, θ had declined and stabilized at .016. However, none of the point estimates of θ during or after the transition period were different from zero.

The results from the switching model are examined and interpreted in light of actual developments in the industry. The year 1977, which the model identifies as the beginning of the transition period, is actually the year during which structural change has started in the industry. The end of the seventies is considered a milestone in the beef industry due to a structural decline in beef consumption. Purcell argues that this development was responsible for much of industry's rush to cost-cutting consolidations, and hence increased concentration, in order to compete with other meats such as poultry. The four firm concentration ratio (CR_4) from 1977 to 1988 has increased from 29.1 to 69.7.

Marion and Kim noted that the 1977-1988 period can be divided into two separate time periods during which different economic forces contributed to the sharp increase in the CR_4. Between 1977 and 1982, a period roughly consistent with the model's transition period, the CR_4 increased from 29.1 to 45.0. Marion and Kim attributed the increase in concentration from 1977 to 1982 to a decline in total industry capacity and the impact of internal expansion by leading firms in the industry. Consolidations in the industry during that period accounted for only half a percent of the increase in the CR_4.

Between 1982 and 1988, a period consistent with the model's second regime, the CR_4 increased from 45.0 to 69.7. This time, mergers and acquisition in the industry accounted for more than 19 percent in the increase in concentration. The CR_4 would have been about

50.3 had the mergers not taken place.

However, one important question is why the transition to competitive conduct by the industry during a period of increased concentration. Two factors may be important. As larger plants were built in the industry during the 1980's, competition to keep those plants operating at maximum slaughter efficiency may have broken oligopsonistic interdependence. Second, increases in concentration ratios and allegations on non-competitive pricing of live cattle generated several lawsuits and federal government investigations after 1975 which may have restrained the exercise of market power. Ward documents a series of actions against meat-packers during the 1975-1983 period including antitrust lawsuits by groups of cattle producers. Several studies or investigations by various government agencies including the Justice Department, the Federal Trade Commission, the Packers and Stockyard Administration have also taken place during that period.

Summary and Conclusions

This paper presented and empirical model for testing switching market conduct in an oligopsonistic industry. The model adapts Bresnahan's procedure for identifying the oligopoly solution and the switching regression model suggested by Ohtani *et al.* Applied to the U.S. beef slaughter industry, the results show two distinct regimes of conduct in the industry during the 1960-1987 period. The period from 1960 to 1977 was characterized by noncompetitive conduct. A regime of competitive conduct took place after a transition period lasting from 1978 to 1982. The changes in conduct identified by the switching model seem to be consistent with the time periods during which the industry has undergone major structural change.

References

Alexander, D. L. "An Empirical Test of Monopoly Behaviour: an Application to the Hardwood Case." *Applied Economics* 20(1988):1115-27.

Baker, J. B. "Identifying Cartel Policing under Uncertainty: the U.S. Steel Industry, 1933-1939." *Journal of Law and Economics* 32(1989):s47-s76.

Brander, J. A. and A. Zhang. "Market Conduct in the Airline Industry: An Empirical Investigation." *Rand Journal of Economics* 21(1990):567-583.

Bresnahan, T. F. "The Oligopoly Solution Concept is Identified." *Economic Letters* 10(1982):87-92.

Buschena, D. E. and J. M. Perloff. "The Creation of Dominant Firm Market Power in the Coconut Oil Export Market." *American Journal of Agricultural Economics* 73(1992):1000- 1008.

General Accounting Office. *Packers and Stockyards Administration: Oversight of Livestock Market Competitiveness Needs to be Enhanced*, GA0/RECD-92-36, 1991.

Lau, L. J. "On Identifying the Degree of Competitiveness from Industry Price and Output Data." *Economic Letters* 10(1990):93-106.

Libecap, G. D. "The Rise of Chicago Packers and the Origins of Meat Inspection and Antitrust." *Economic Inquiry* 30(1992):242-262.

Lopez, R. A. and D. Dorsainvil. "An Analysis of Pricing in the Haitian Coffee Market." *Journal of Developing Areas* 34(1990):93-106.

Marion, G. and D. Kim. "Concentration Change in Selected Food Manufacturing Industries: the Influence of Mergers vs. Internal Growth." *Agribusiness: An International Journal* 7(1991):415-432.

Ohtani, K., S. Kakimoto and K. Abe. "A Gradual Switching Regression Model with Flexible Transition Path." *Economic Letters* 32(199):43-48.

Purcell, W. D. "Economics of Consolidation in the Beef Sector: Research Challenges." *American Journal of Agricultural Economics* 72(1990):1210-1218.

Shaffer, S. Non-Structural Measures of Competition: Toward a Synthesis of Alternatives." *Economic Letters* 12(1983):349-353.

Shaffer, S. "Competition in the U.S. Banking Industry, *Economic Letters* 29(1989):321-323.

Schroeter, J. R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Review of Economics and Statistics* 70(1988):158-162.

Schroeter, J. R. and A. Azzam. "Measuring Market Power in Multi-Product Oligopolies: the US Meat Industry." *Applied Economics* 22(1990):1365-1376.

TABLE 1. Coefficient Estimates of the Supply Equation.

Explanatory Variable	Parameter	Estimate	t-ratio
Intercept	α_o	-6722.10	-1.336
Price of Steers (w_t)	α_1	232.55	2.676
Price of Corn (F_t)	α_2	30.595	1.234
Price of Steers ×			
Cattle Inventory (C_t)	α_3	0.171	2.698
Price of Corn ($w_t.F_t$)	α_4	-0.744	-1.505

*Asymptotic t-values in parentheses. Asterisk indicates significance at .05 confidence interval.

TABLE 2. Coefficient Estimates of the Derived Demand Equation.

Explanatory Variable	Parameter	Estimate	t-ratio
Intercept	β_o	-34.819E+03	-11.172E+03
Q^*_{Bt}	θ	0.928E+03	1.4520000
	λ_1	-01.2120000	-5.9590000
	λ_2	0.0230000	5.7530000
Quantity of Beef (Q_{Bt})	β_1	-0.315E-02	- 9.1020000
Quantity of Pork (Q_{Pt})	β_2	-0.304E-03	- 0.9650000
Quantity of Poultry (Q_{Ct})	β_3	-0.248E-02	3.5150000
Income (I_t)	β_4	3.1420000	6.1520000
Wage Rate (W_t)	β_5	4.8690000	5.2850000

*Asymptotic t-values in parentheses. Asterisk indicates significance newline at .05 confidence interval.

Sjostrom, W. "An Empirical Test of Monopoly Behaviour: An Application to the Hardwood Case: a Comment." *Applied Economics* 23(1991):339-341.

Thurman, W. N. "Endogeneity Testing in a Supply and Demand Framework." *Review of Economics and Statistics* 68(1986):638-646.

Ward, C. E. *Meatpacking Competition and Pricing.* Blacksburg, Virginia: Research Institute on Livestock Pricing, 1988.

Yeager, M. *Competition and Regulation: the Development of Oligopoly in the Meat-Packing Industry.* Greenwich, CT: JAI Press, 1981.

FIGURE 1.

Transition Path for Measure of Market Conduct