Dynamic Assessment of Oligopoly, Oligopsony Power, and Cost Efficiency using the New Empirical Industrial Organization in the U.S. Beef Packing Industry

In Bae Ji
Graduate Research Assistant
Oklahoma State University
Stillwater, OK 74078
Phone: 405-744-9969
Fax: 405-744-8210
inbae.ji@okstate.edu

Chanjin Chung
Professor
Oklahoma State University
Stillwater, OK 74078
Phone: 405-744-6164
Fax: 405-744-8210
chanjin.chung@okstate.edu

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010

Abstract

In this paper, the new empirical industrial organization approach with a dynamic model is simultaneously employed to measure the degree of oligopoly, oligopsony power, and cost efficiency in the U.S. beef packing industry. The oligopsony power is estimated with two effects: cash cattle procurement market power and captive supply market power. The model is estimated by the Generalized Method of Moments using monthly data from 1990 to 2006. The empirical results reveal the presence of market power in both the beef retail market and the cattle procurement market in the sample period. The captive supply is a source of oligopsony market power, but the effect is considerably small. The oligopsony market power is greater and less stable than oligopoly market power for the whole sample period. The cost efficiency effect outweighs the market power effects for the sample period.

Keywords: beef packing industry, captive supply, cost efficiency, industrial concentration, market power, NEIO

Dynamic Assessment of Oligopoly, Oligopsony Power, and Cost Efficiency using the New Empirical Industrial Organization in the U.S. Beef Packing Industry

Introduction

Several issues are concerned with market power in the U.S. beef packing industry. Among these market power issues, concentration and captive supply[1] are the most controversial issues. A wave of mergers and consolidations in the beef packing industry began in the late 1970's and continued until the early 1990's (Azzam 1997). Especially during the recent decades, the concentration of the beef packing industry has gradually increased. The four-firm concentration ratio in terms of boxed beef supply increased from 52.9 percent in 1980 to 84.7 percent in 2000, while the ratio in terms of cattle slaughter increased from 28.4 percent in 1980 to 71.2 percent in 2003. As a form of backward integration by packers, the captive supply has also continuously increased over the last two decades. The captive supply ratio as a total cattle slaughter also continuously increased from 20.5 percent in 1988 to 44.4 percent in 2002 (USDA). With horizontal merger and concentration, it is unclear whether cost efficiency gains from increased concentration outweigh potential market power effects. It is also disputable whether captive supply increases efficiency of reducing transaction costs and market risk or it reduces competition and increase the market power of packers.

After Schroeter (1988) introduced the new empirical industrial organization (NEIO) in agricultural economics, many studies have measured market power. These NEIO

[1] The definition of captive supply by USDA Grain Inspection, Packers and Stockyards Administration (GIPSA) includes animals procured through forward contracts, marketing agreements, and packer feeding arrangements or otherwise committed to a packer more than 14 days prior to slaughter.

approaches in agricultural economics are well reviewed by several researchers such as Sexton (2000), Sheldon and Sperling (2002), and Whitley (2003). Among the articles that use NEIO approaches, several studies try to compare market power and cost efficiency. Most industrial organization literature suggests that a merger's efficiency gain offsets consumers' potential welfare losses (Azzam and Schroeter 1995; Azzam 1997; Sexton 2000; Tostao and Chung 2005). However, Lopez, Azzam, and Espana (2002) find that market power effects dominate cost efficiency effects in most food industries, and that further increases in concentration would increase output price. Numerous studies are concerned with captive supply. These studies focus on the relationship between the captive supply and cash market price to investigate the effect of captive supply on the beef procurement market. Many studies report a negative relationship between captive supply and cash market price (Ward, Koontz, and Schroeder 1998; Schroeter and Azzam 2004). Also most researchers believe that this negative relationship reflects market power of the packer as a buyer that uses the captive supply to press cash market price in the cattle procurement market (Schroeder et. al. 1993; Ward, Koontz, and Schroeder 1998; Zhang and Sexton 2000). These studies focus on dealing with the relationship between captive supply and cash market price rather than looking into the effect of captive supply in the industrial level.

The previous studies have some limitations. First, most studies assume that the processing firms have oligopsony power in the cattle procurement market (Azzam and Schroeter 1995; Azzam 1997), while others assume the wholesalers have oligopoly power in the beef market (Lopez, Azzam, and Espana 2002). Allowing for market power in procuring firm inputs while ignoring the potential market power in selling final outputs is likely to understate market power effects or vice versa[2] (Tostao and Chung 2005). Additionally, Only one study deals with the captive supply in the NEIO model (Zheng and Vukina 2009). However, this study focuses only on the captive supply market power for the average firm rather than dealing with both the captive supply and the concentration for the industrial level in the pork packing industry. Therefore, in this study, the oligopoly and oligopsony market powers are simultaneously considered, and the oligopsony market power is separated by two effects: cash cattle procurement market effect and captive supply effect. Finally, the concentration change is considered in the NEIO model. That is, we extend Zheng and Vukina (2009)'s model to a more general model that includes concentration effect in the NEIO model.

Second, conjectural variations such as market conduct parameters are prominent components in the NEIO approach. Conjectural variations measure the overall market reaction to an individual firm's change in output supply and input demand. However, these previous studies assume that the conjectural variation is constant throughout the sample period. Therefore, they are limited in explaining how market power and efficiency change with evolving industry structure over time.

The objective of this paper is threefold. First, the effect of cost efficiency and market power by increasing concentration in the U.S. beef packing industry is measured considering market power exerted through both oligopoly and oligopsony simultaneously.

[2] Ignoring this important variable can induce omitted variable problems. If the omitted variable is uncorrelated with right-hand side variables then the estimate will only lose all efficiency properties, but if the omitted variable is correlated with right-hand side variables then the estimate will lose all properties so that the estimate is biased and inconsistent. (Greene 2008).

Second, the oligopsony market power for captive supply is separately estimated from the cash cattle procurement market in the NEIO model. Third, the changes of market powers and efficiencies in the beef retail and cattle procurement market are measured for the U.S. beef packing industry during the 1990-2006 time period using monthly data. This paper extends the existing literature of market power related to the U.S. beef packing industry by including captive supply market power and by examining the dynamic oligopoly and oligopsony powers jointly over the past several decades. The results of this paper will be helpful to understand the structure and change of market power behavior in the U.S. beef packing industry.

The Model

Generally, two approaches exist in the theoretical framework of conjectural elasticity (Wann and Sexton 1992; Mei and Sun 2008). One is the primal production function-based approach (Azzam and Pagoulatos 1990; Mei and Sun 2008) and the other is the dual approach based on a cost function (Schroeter 1988; Azzam 1997; Lopez, Azzam, and Espana 2002; Tostao and Chung 2005). In this paper, we use the dual approach because of an absence of quantity data for the output and input at the firm level.

In view of the intended application, we assume beef processors and retailers are integrated in a single “processing-retailing” sector that is allowed to have oligopoly and oligopsony market power simultaneously (Tostao and Chung 2005). We assume a beef processing-retailing industry consisting of N firms converting a single farm input, cattle, into a final output, beef. We assume two procurement channels: the cash market and the captive supply and that the captive supply for each period is given because the captive supply is determined before the packer decides the amount of cattle procured from the cash market. Therefore, the firms determine the cattle procured from the cash market to maximize the firm's profit. We assume each farmer is faced with a competitive market to sell cattle to packers. Each firm's processing technology is characterized by fixed proportions between the farm input and the output (Schroeter 1988; Azzam 1997). Conversion of the farm input into output requires non-farm inputs that are purchased in competitive markets and used in variable proportions. Each firm sells the homogenous output to consumers who buy the output competitively in a market. Therefore, each firm is not necessarily a price-taker both in the cattle procurement market and in the beef retail market. Profit, π_i, for the i th firm (for $i = 1, 2, \ldots, N$) is

(1) $$\pi_i = P(Q)(q_{1i} + q_{2i}) - W_1(Q_1)q_{1i} - W_2(Q_1)q_{2i} - C_i(q_i, \mathbf{v}),$$

where P is the beef retail price, W_1 is the cash market cattle input price, W_2 is the captive supply cattle input price, q_{1i} is the i th firm's beef product or cattle input from the cash market, q_{2i} is the i th firm's beef product or cattle input from the captive supply, $q_i = q_{1i} + q_{2i}$ is the i th firm's total beef product or total cattle input, $Q = \sum_i^N q_i$ is the industry's total beef product or the industry's total cattle input, $C_i(q_i, \mathbf{v})$ is the processing cost function for the i th firm, and $\mathbf{v}$ is a vector of prices of nonfarm inputs. The first order condition for profit maximizing is

(2) $$\frac{\partial \pi_i}{\partial q_{1i}} = P - W_1 + \left(\frac{\partial P}{\partial Q}\frac{\partial Q}{\partial q_{1i}}\right)(q_{1i} + q_{2i}) - \frac{\partial W_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_{1i}}q_{1i} - \frac{\partial W_2}{\partial W_1}\frac{\partial W_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_{1i}}q_{2i} - c_i(q_i, \mathbf{v}) = 0\,.$$

Rearranging the first order condition and re-writing it in elasticity form yields

$$(3)\qquad P = W_1 - \frac{(1+\phi_i)}{\varepsilon_d} s_i + \frac{(1+\phi_i)}{\varepsilon_s} s_i + \frac{\eta(1+\phi_i)}{\varepsilon_s}\frac{q_{2i}}{q_{1i}} s_i + c_i(q_i, \mathbf{v}),$$

where $(1+\phi_i) = \frac{\partial Q}{\partial q_{1i}} = \frac{\partial Q_1}{\partial q_{1i}}$, $\phi_i = \partial \sum_{h \neq i}^{n} q_{1h} \Big/ \partial q_{1i}$ is the i th firm's conjecture about rivals' responses to a change in final product sales and in cattle purchases, $\varepsilon_d = (\partial Q/\partial P)(1/Q)$ and $\varepsilon_s = (\partial Q_1/\partial W_1)(1/Q_1)$ are the semi-elasticities of retail demand and semi-elasticities of farm supply for cash market respectively, $\eta = \frac{\partial W_2}{\partial W_1}$ is the change of the captive supply price with respect to the change of cash market price, $s_i = q_i/Q$ is the i th firm's market share in retail market and cattle procurement market, and $c_i(q_i, \mathbf{v}) = \partial C(q_i, \mathbf{v})/\partial q_{1i}$ is the marginal cost for the i th firm.

Following Azzam, the i th firm's cost function is assumed to take the generalized Leontief form:

$$(4)\qquad C_i(q_i, \mathbf{v}) = q_i \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + (q_i)^2 \sum_j \beta_j v_j .$$

The optimizing condition (3) becomes

$$(5)\qquad P = W_1 - \frac{(1+\phi_i)}{\varepsilon_d} s_i + \frac{(1+\phi_i)}{\varepsilon_s} s_i + \frac{\eta(1+\phi_i)}{\varepsilon_s}\frac{q_{2i}}{q_{1i}} s_i + \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + 2q_i \sum_j \beta_j v_j .$$

Multiplying (5) by each firm's market share, (q_i/Q), and summing across all N firms in the industry yields

(6)
$$\sum_i^n s_i P = \sum_i^n s_i W_1 - \sum_i^n s_i \frac{(1+\phi_i)}{\varepsilon_d} s_i + \sum_i^n s_i \frac{(1+\phi_i)}{\varepsilon_s} s_i + \sum_i^n s_i \frac{\eta(1+\phi_i)}{\varepsilon_s} \frac{q_{2i}}{q_{1i}} s_i + \sum_i^n s_i \left(\sum_k \sum_j \alpha_{kl} (v_k v_j)^{1/2} + 2q_i \sum_j \beta_j v_j \right).$$

Rearranging equation (6) yields the industry pricing equation as:

(7) $$P = W_1 - \frac{(1+\Phi)H}{\varepsilon_d} + \frac{(1+\Phi)H}{\varepsilon_s} + \frac{\eta(1+\Phi)H}{\varepsilon_s} \frac{Q_2}{Q_1} + \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + 2HQ \sum_j \beta_j v_j + e_m,$$

where $H = \sum_i (s_i)^2$ is the Herfindahl index in the retail beef market and in the cattle procurement market, $\Phi = \sum_i (q_{1i})^2 \phi_i \big/ \sum_i (q_{1i})^2$ is weighted conjectural variation in the retail output market and in the farm input market, and e_m is the error term for the margin equation (Cowling and Waterson 1976; Dickson 1981; Azzam 1997).

In equation (7), the first three terms in the right-hand side capture market power in the beef retail market, in the ash cattle procurement market, and in the captive supply respectively in the industrial level. The fourth term captures marginal cost for the integrated processing/retailing sector in the industrial level. The value of $\Phi = -1$ means there is no mark-up or mark-down, that is, all firms are price-takers in the beef retail market and in the cattle procurement market, so that the output price or the farm-input price is unchanged. The value of $\Phi = 0$ implies Cournot monopoly and monopsony. For noncompetitive conduct, concentration affects all mark-up, mark-down, and marginal cost. Appelbaum (1982) defines conjectural variation elasticity as $\Phi^* = (1+\Phi)H$, which ranges between 0 and 1. The price elasticity of demand for the beef market and the price elasticity of supply for the cash cattle market are given by $E_d = \varepsilon_d P$ and $E_s = \varepsilon_s W_1$ respectively. Then the industry oligopoly power is defined by $L^{retail} = -\Phi^* / E_d$, and oligopsony power for the cash market and the captive supply are defined by $L^{cash} = \Phi^* / E_s$ and $L^{captive} = \theta \Phi^* / E_s$ respectively, where $\theta = \eta Q_2 / Q_1$. The value $\Phi^* = 0$ denotes perfect competition; $\Phi^* = 1$ denotes pure monopoly or monopsony; and other values denote various degrees of oligopoly or oligopsony power with higher values of Φ^* denoting greater departures from perfect competition (Mei and Sun 2008).

Market power effects from an increase of concentration in the processing/retailing industry can be separated from cost efficiency effects by differentiating equation (7) with respect to the Herfindahl index in the processing/retailing industry (H) as:

(8) $$\frac{\partial P}{\partial H} = -\frac{(1+\Phi)}{\varepsilon_d} + \frac{(1+\Phi)}{\varepsilon_s} + \frac{\eta(1+\Phi)}{\varepsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j .$$

The first three terms in the right-hand side of equation (8) capture market power effects in the integrated processing/retailing sector, and the fourth term captures cost savings for the integrated processing/retailing sector (Azzam 1997; Lopez, Azzam, and Espana 2002).

To test captive supply effect on market power, the oligopsony market power in equation (7) is differentiated with respect to captive supply, Q_2 , and then we obtain

(9) $$\Theta = \frac{\partial L^{captive}}{\partial Q_2} = \frac{\eta(1+\Phi)H}{\varepsilon_s}\frac{1}{Q_1},$$

where Θ is the captive supply effect on market power. The value of $\Theta = 0$ implies that the change of captive supply has no impact on the oligopsony market power.

The first null hypothesis is that oligopoly market power and two oligopsony market powers in the U.S. beef packing industry equal zero. Rejecting it should suggest that the U.S. beef packing industry exerts market power in either the beef retail market or the cash cattle procurement market, or the captive supply, or all. The second null hypothesis is that increasing captive supply has no effect on the oligopsony market power. Rejecting it suggests that captive supply is a source of oligopsony market power for packers. The third null hypothesis is that by increasing concentration, the cost efficiency effect outweighs market power effect. Rejecting it suggests that an increase of concentration in the U.S. beef packing industry will decrease social welfare.

Data

This paper uses monthly data series for the U.S. beef packing industry ranging from 1990 to 2006. The cattle slaughter total live weight, which is used as the total beef production or the total cattle input supply is from Livestock Slaughter Annual Summary of United States Department of Agriculture (USDA). The cash market cattle price data is combined from several long-term fed cattle price history (monthly) data sets of the USDA Economic Research Service (ERS) which have reported the Nebraska direct fed steer price. The weighted captive supply price is combined from the USDA Agricultural Marketing Services (AMS) Mandatory Price Report (MPR) data. The retail price of beef, the retail price of pork, the wholesale price of chicken, the corn price, and the calf price are from USDA National Agricultural Statistics Service (NASS) and ERS. The fuel oil number 2 price is obtained from the Consumer Price Index Database of the Bureau of Labor Statistics

(BLS). Per capita income data is from the econstats site (http://www.econstats.com). The consumer price index for meat and the producer price index for farm product are from BLS. The price index and the productivity index of labor for the U.S. animal slaughtering and processing industries are obtained from the Industry Productivity and Costs Database of BLS. The price index and the productivity index of capital and material for U.S. food and other industry are obtained from the Major Sector Multifactor Productivity Index Database of BLS. The Herfindahl index for the U.S. beef processing industry is the cattle slaughter concentration index (and boxed beef concentration index) compiled from several annual reports from the Packers and Stockyards Statistical Report (1996-2006). The four firms captive supply ratio is also from the Packers and Stockyards Statistical Report. The definitions and descriptive statistics of these variables are presented in table 1.

Empirical procedures

To estimate the margin equation (7), simultaneous equations are needed such as three non-farm input demand equations: the farm input (cattle) supply equation, the retail output (beef) demand equation, and the captive supply price equation. Non-farm input demands are obtained by applying Shephard's lemma on the industry level processing cost function represented by equation (4) as:

(10)
$$\frac{\partial C(Q,\mathbf{v})}{\partial v_j} = Q\sum_k \alpha_{kj}\left(\frac{v_k}{v_j}\right)^{1/2} + \beta_j HQ^2,$$

which can be re-arranged as:

(11) $$\frac{X_j}{Q} = \sum_k \alpha_{kj} \left(\frac{v_k}{v_j} \right)^{1/2} + \beta_j HQ + e_j ,$$

where X_j is the industry level derived non-farm input demand, v_j and v_k are the input price of labor and capital and material, and e_j is the error term for the non-farm input demand function.

Cattle supply and beef demand equations take the semi-logarithmic forms which are specified as:

(12) $$\ln Q_1 = \gamma_0 + \varepsilon_s W_1 + \gamma_1 P^{corn} + \gamma_2 P^{sorghum} + \gamma_3 P^{calves} + \gamma_4 P^{fuel} + e_s ,$$

(13) $$\ln Q = \delta_0 + \varepsilon_d P + \delta_1 P^{pork} + \delta_2 P^{chicken} + \delta_3 INCOME + e_d ,$$

where $\varepsilon_s = \frac{\partial Q}{\partial W} \frac{1}{Q}$ is the semi-elasticity of supply, $\varepsilon_d = \frac{\partial Q}{\partial P} \frac{1}{Q}$ is the semi-elasticity of demand, and e_s and e_d are the error terms for supply and demand equations respectively.

Finally, the captive price can be a function of the cash market price because the price of cattle through marketing agreement and forward contract as captive supply is calculated by using various formulas that include base price, quality characteristics, and a system of premia and discounts. These formulas are tied to cash market price (Schroeter and Azzam 2004). The price of captive supply is modeled as:

(14) $$W_2 = \sigma_0 + \eta W_1 + \sigma_1 Q_2 + e_w ,$$

where W_1 is the cash market price, W_2 is the captive supply price, Q_2 is the cattle quantity procured through the captive supply, and e_w is the error term for the captive supply equation. However, the data for captive supply price is not available before the advent of the mandatory price report, so this equation (14) is separately estimated to find the value, η, with the monthly data from 2003 to 2007. The result of estimation[3] shows that η is 0.7229. This value is not much different from Zheng and Vukina (2008)'s value, 0.7835; they estimated the similar equation for the pork industry.

Static Estimation by GMM

Equations (7), (11), (12), (13), and (14), which constitute a system of seven equations in total are estimated. However, we estimate six equations except the equation (14) because the data is not available. When estimating the systems, endogeneity problems will occur. To deal with endogeneity problems in the simultaneous equations, we employ an instrumental variable estimator, generalized method of moments (GMM). Also, GMM is used because the Breushch-Godfrey test for autocorrelation (Breusch 1978; Godfrey 1978) rejects the null hypothesis of no first-order autocorrelation on each equation's residuals. Note that the estimated standard errors for GMM estimates are considerably smaller than those for 3SLS or LIML (Green 2008). The nineteen instrumental variables included in the equation are the Herfindahl indices for the boxed beef production market and for the cattle procurement market, four-firm concentration ratio for cattle procurement market, beef price, cattle cash price, cattle price, four-firm captive supply ratio, labor price, capital price, material price, corn price, sorghum price, calves price, fuel price, pork price, chicken price, income, time, and squared time.

---

[3] In the estimation, we tested the RESET test with linear model specifications with three variables such as W_1, Q_2, and $time$. The RESET test shows that the above model is not inappropriate for the power 2, 3, and 4 at the 5% significance level. Additionally, this model has an autocorrelation problem, so we used GLS to estimate the parameters, η, σ_0, and σ_1.

Dynamic Estimation by GMM

The above econometric specification can only estimate the static market conduct parameters, Φ. It cannot measure and demonstrate their possible changes over time. We treat the equilibrium market conduct parameters as a function of the exogenous variables, four-firm concentration ratio, CR, and captive supply ratio, $CAPR$, as:

(15) $$\Phi = c_0 + c_1 CR + c_2 CAPR \ .$$

Then equation (7) can be changed as:

(16) $$\begin{aligned} P = W_1 &- \frac{(1 + c_0 + c_1 CR + c_2 CAPR)H}{\varepsilon_d} + \frac{(1 + c_0 + c_1 CR + c_2 CAPR)H}{\varepsilon_s} \\ &+ \frac{\eta(1 + c_0 + c_1 CR + c_2 CAPR)H}{\varepsilon_s}\frac{Q_2}{Q_1} + \sum_k \sum_l \alpha_{kj}(v_k v_j)^{1/2} + 2HQ\sum_j \beta_j v_j \ . \end{aligned}$$

We can also find equation (17) by differentiating equation (16) with respect to the Herfindahl index (H) as:

(17) $$\begin{aligned} \frac{\partial P}{\partial H} = &- \frac{(1 + c_0 + c_1 CR + c_2 CAPR)}{\varepsilon_d} + \frac{(1 + c_0 + c_1 CR + c_2 CAPR)}{\varepsilon_s} \\ &+ \frac{\eta(1 + c_0 + c_1 CR + c_2 CAPR)}{\varepsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j \ . \end{aligned}$$

This allows the conjectural variation parameter, Φ, to vary over time, reflecting changes in the economic environment[4] (Azzam 1997; Mei and Sun 2008). Equation (17) measures concentration effects on output price of the dynamic market conduct, while equation (8) measures those of the static market conduct.

---

[4] Azzam (1997) and Lopez, Azzam, and Espana (2002) tried to use time varying models as a function of Herfindahl index. However they failed to reject the null hypothesis that the conjecture variation parameter, Φ, is a constant. Mei and Sun (2008) modeled time varying model as a function of four-firm concentration ratio and average mill capacity. Schroeter (1988) also modeled as a function of labor input price, capital input price, and time trend for time varying model.

Equations (16), (11), (12), and (13), which constitute a system, are estimated for dynamic model. The dynamic market conduct parameter, Φ^*, and market power L^{retail}, L^{cash}, and $L^{captive}$ can be estimated using the estimated values of c_i, four-firm concentration ratio, captive supply ratio, and estimated supply and demand elasticities. The concentration effects on the output price of the dynamic market conduct and their standard error are also estimated through GMM using the MODEL Procedure in SAS 9.1.

Empirical Results

The estimation results of the static model by GMM are reported in table 2. By t-statistics, 20 of the 21 parameter estimates are statistically significant at the 5% significance level. For the key parameters, conjectural variation, Φ, is -0.6838 and statistically significant at the 5% significance level. The conjectural variation is tested for pure monopoly or pure monopsony, $\Phi = 0$, and for perfect competition, $\Phi = -1$. Both null hypotheses are rejected at the 5% significance level. So we can conclude that oligopoly and oligopsony conducts exist in the U.S. beef packing industry. The semi-elasticities of supply and demand are 0.0069 and -0.0020, respectively. They are also statistically significant at the 5% significance level. Based on these results, the conjectural elasticities, Φ^*, oligopoly market power, L^{retail}, oligopsony market power for cash market, L^{cash}, and oligopoly market power for captive supply, $L^{captive}$, are calculated in table 3. The conjectural elasticity is 0.0440, the oligopoly market power, L^{retail}, is 0.1041, the oligopsony market power for cash market, L^{cash}, is 0.946, and the oligopsony market power for captive supply, $L^{captive}$, is 0.0294. They are all significant at the 5% significance level. These results imply that market power exists in both the beef retail and cattle procurement markets. The oligopsony market power for captive supply is considerably smaller compare to the oligopsony market power for cash market, but the oligopsony power is slightly larger than the oligopoly power. This result coincides with the findings of Tostao and Chung (2005).

In contrast to the static estimation, the dynamic model allows conjectural elasticity and market powers to change over time. In the dynamic model, we assume conjectural elasticity is a function of four-firm concentration and captive supply ratio, so we can calculate the conjectural elasticity and market powers for each year. The parameter estimates and the statistics for the model are reported in table 5. The magnitude of parameter estimates and overall fit are comparable to those from the static GMM estimation. The dynamic conjectural elasticity and market powers from 1990 to 2006 are presented in table 6. They are all statistically significant at the 5% significance level. The oligopoly power is still slightly smaller than the oligopsony power. The oligopoly and oligopsony market powers are gradually decreasing with time after 1990, which is not consistent with the change of the concentrate rates (Herfindahl indices) in both the beef retail and cattle cash procurement market, but the oligopsony market power for captive supply gradually increases with the increase of captive supply. Over 1990-2006, the maximum value of oligopoly market power is 0.1131 in 1990, the minimum is 0.0658 in 2004, and the average is 0.0906, but the maximum value of oligopsony power is 0.1266 in 1990, the minimum is 0.0869 in 2003, and the average is 0.1119. The results show that oligopsony power is slightly larger and less stable than oligopoly power.

The effect of captive supply on market power, $\Theta = 0$, is tested. The value of Θ is 0.0276 in the static model, and 0.0249 in the dynamic model, and both of them are statistically significant at the 5% significance level. This result means that by increasing captive supply, the oligopsony market power expands.

In the static and dynamic model, the marginal effects of market concentration on market powers and cost efficiency are calculated by equations (8) and (17) in table 4 and table 7. The oligopoly effect, the oligopsony effect for cash market and captive supply, the cost efficiency effect, and the total net effect are 155.68, 45.91, 14.27, -446.98, and -231.12 respectively in the static model. They are all statistically significant at the 5% significance level. For the dynamic model, the oligopoly effect, the oligopsony effect for cash market and captive supply, the cost efficiency effect, and the total net effect are calculated for each year. The average values are 135.57, 41.26, 12.81, -199.54, and -9.88 respectively. They are also statistically significant at the 5% significance level. These results imply a mark-up effect on the beef price by increasing concentration in both oligopoly and oligopsony markets while cost efficiency also exists by increasing concentration. The cost efficiency effect dominates the market power effects in both the static and dynamic model but is significantly smaller in the dynamic model. This result is consistent with the findings of Azzam and Schroeter (1995), Azzam (1997), Sexton (2000), and Tostao and Chung (2005) but contradict those of Lopez, Azzam, and Espana (2002).

In summary, the null hypotheses that the oligopoly market power and oligopsony market power in the U.S. beef packing industry equal zero are rejected in the static and dynamic model. Therefore, we can conclude that the U.S. beef packing industry exerts market power in both the beef retail market and the cattle procurement market but the oligopsony market power is slightly larger than the oligopoly market power. The second null hypothesis that captive supply has no effect on oligopsony market power is rejected. This conclusion implies that packers use captive supply as a source of market power, but the market power from captive supply is small. The third null hypothesis that by increasing concentration the cost efficiency effect outweighs market power effects fails to reject in both the static and dynamic models. So, we can conclude that an increase of concentration in the U.S. beef packing industry increases social welfare.

Conclusions

During the last two decades, concentration and captive supply have been controversial issues as sources of market power in the U.S. beef packing industry. This paper contributes two fold to the measurement of market power in the U.S. beef packing industry. First, the oligopoly and oligopsony market powers are simultaneously considered, and the oligopsony market power is divided by two effects: captive supply market power and cash cattle procurement market power. Therefore, the NEIO approach can measure the market power of retail market, cash cattle market, and captive supply as a function of concentration. Second, the time varying model is applied to look into the dynamic change of market conducts such as conjectural variation and market power. Consequently, we can dynamically calculate the change of concentration effect on market power and cost efficiency in the U.S. beef packing industry. To estimate the simultaneous equations, monthly data from 1990 to 2006 are used in the estimation.

The empirical results reveal the presence of market power in both the beef retail market and the cattle procurement market in the past two decades. The oligopsony market power is slightly greater and less stable than oligopoly market power, but the difference in magnitude between oligopoly and oligopsony market power is small for the whole sample period. Additionally, further increases in concentration would expand market power in both oligopoly and oligopsony markets. However, the oligopoly and oligopsony market powers are slightly decreased during the sample period even though the concentration is slightly increased from 1990 to 2006. This result may be from other market circumstances. The increase of captive supply leads to the increase of oligopsony market power, but the market power by captive supply is a relatively small portion of the total market power. Therefore, we can conjecture that the majority of market power would be caused by concentration rather than captive supply. The results also show that the cost efficiency effects from the increased concentration in the U.S. beef packing industry are considerably larger than the market power effects in the static model, but slightly lager in the dynamic model. This result means that the cost efficiency effect outweighs the market power effects.

Reference

Appelbaum, E. 1982. "The Estimation of the Degree of Oligopoly Power." *Journal of Econometrics* 19:287-299.

Azzam, A.M. and E. Pagoulatos. 1990. "Testing Oligopolistic and Oligopsonistic Behavior: An Application to the U.S. Meat-Packing Industry." *Journal of Agricultural. Economics*. 41: 362-370.

____. and J.R. Schroeter. 1991. "Implications of Increased Regional Concentration and Oligopsonistic Coordination in the Beef Packing Industry." *Western Journal of Agricultural Economics* 16(2):374-381.

____. 1997. "Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration." *The Journal of Industrial Economics* 45(4):377-386.

Breusch, T.S. 1978. "Testing for Autocorrelation in Dynamic Linear Model." *Australian Economic Paper* 17:334-335.

Cowling, K.G. and Waterson, M. 1976. "Price-Cost Margins and Market Structure." *Economica* 43:267-274.

Dickson, V.A. 1981. "Conjectural Variation Elasticities and Concentration." *Economics Letters* 7:281-285.

Econstats Database. Available at http://www.econstats.com/

Godfrey, L.G. 1978. "Testing Against General Autoregressive and Moving Average Error Models When the Regressors Include Lagged Dependent Variables." *Econometrica* 46:1293-1302.

Greene, W.H. 2008. *Econometic Analysis*. New York University: Prentice-Hall Inc.

Lopez, R.A., A.M. Azzam, and C.L. Espana. 2002. "Market Power and/or Efficiency: A Structural Approach." *Review of Industrial Organization* 20:115-126.

Mei, B. and C. Sun. 2008. "Assessing Time-Varying Oligopoly and Oligopsony Power in the U.S. Paper Industry." *Journal of Agricultural and Applied Economics* 40(3):927-939.

Schroeder, T.C, R. Jones, J. Mintert, and A.P. Barkley. 1993. "The Impact of Forward Contracting on Fed Cattle Transaction Prices." Review of Agricultural Economics 15(2):325-337.

Schroeter, J.R. 1988. "Estimating the Degree of Market Power in the Beef Packing Industry." *The Review of Economics and Statistics* 70(1):158-162.

Schroeter, J. R. and A. Azzam. 2004. "Captive supplies and cash market prices for fed cattle: The role of delivery timing incentives." *Agribusiness* 20:347-362.

Sexton, R.J. 2000. "Industrialization and Consolidation in the US Food Sector: Implications for Competition and Welfare." *American Journal of Agricultural Economics* 82:1087-1104.

Sheldon, I. and R. Sperling. 2002. "Estimating the Extent of Imperfect Competition in the Food Industry: What Have We Learned?" *Journal of Agricultural Economics* 54-1: 89-109.

Tostao, E. and C. Chung. 2005. "Horizontal Consolidation in the U.S. Food Processing Industry: Boon or Bane?" Paper presented at the Southern Agricultural Economics Association Annual Meetings in Little Rock, Arkansas, February 5-9.

U.S. Department of Agriculture. Economic Research Service. Meat Price Spreads. Available at http://www.ers.usda.gov/Data/MeatPriceSpreads/

U.S. Department of Agriculture. Grain Inspection, Packers and Stockyards Administration. *Packers and Stockyards Statistical Reports.* Available at http://www.gipsa.usda.gov/GIPSA/webapp?area=newsroom&subject=landing&topic=pub-stat

U.S. Department of Labor. Bureau of Labor Statistics. Available at http://www.bls.gov/

Wann, J.J., and R.J. Sexton. 1992. "Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing." *American Journal of Agricultural Economics* 74:980-990.

Ward, C.E., S.R. Koontz, and T.C. Schroeder. 1998. "Impacts from Captive Cupplies on Fed Cattle Transaction Prices." *Journal of Agricultural and Resource Economics* 23(2):494-14.

Whitley, J. 2003. " The Gains and Losses from Agricultural Concentration: A Critical Survey of the Literature." *Journal of Agricultural & Food Industrial Organization* 1-1.

Zhang, M. and R.J. Sexton. 2000. "Captive Supplies and the Cash Market Price: A Spatial Markets Approach." *Journal of Agricultural and Resource Economics* 25(1):88-108.

Zheng, X. and T. Vukina. 2009. “Do Alternative Marketing Arrangements Increase Pork Packers’ Market Power?” *American journal of Agricultural Economics* 91(1):250-263.

Table 1. Descriptive Statistics of Variables Used in the Empirical Estimation (1990.1-2006.12, N=204)

Variable	Symbol	Mean	S. D.	Minimum	Maximum
Herfindahl index for cattle slaughter	H	0.1390	0.0094	0.1118	0.1507
Cattle slaughter weight (bil./lbs)	Q	3.4674	0.2787	2.8087	4.1485
Retail price of beef (cent/lb)	P	317.77	48.24	271.00	431.72
Cash market price (cent/lb)	W_1	73.46	9.00	58.28	105.5
Captive supply price (cent/lb)	W_2	85.91	5.39	74.62	99.45
4 firm concentration ratio	CR	67.29	3.33	58.6	71.2
4 firm captive supply ratio	$CATR$	28.80	10.04	10.30	52.90
Retail price of pork (cent/lb)	P^{pork}	243.99	27.08	199.33	289.76
Whole. price of chicken (cent/lb)	$P^{chicken}$	37.68	11.99	16.00	66.80
Per capita income (thousand $)	$INCOME$	12.40	1.30	10.47	14.61
Price of calves (cent/lb)	P^{calves}	101.58	20.91	55.40	149.00
Price of corn ($/bushel)	P^{corn}	2.31	0.45	1.52	4.43
Price of sorghum ($/bushel)	$P^{sorghum}$	2.23	0.53	1.41	4.28
Price of fuel oil #2 ($/gallon)	P^{fuel}	1.25	0.47	0.83	2.65
Labor productivity (2000=100)	Q/X_l	100.73	3.11	95.19	109.17
Price of labor (2000=100)	v_l	98.27	7.79	83.50	110.39
Capital productivity (2000=100)	Q/X_c	101.45	1.73	99.53	105.59
Price of capital (2000=100)	v_c	94.51	1.72	99.53	105.59
Material productivity (2000=100)	Q/X_m	102.68	2.76	98.71	109.87
Price of material (2000=100)	v_m	101.96	9.57	87.62	121.27
PPI for farm product (1982=100)	PPI	108.99	8.58	94.30	135.10
CPI for meat (1982=100)	CPI_m	152.57	18.48	126.10	188.50
CPI for fuel (1982=100)	CPI_f	138.22	22.77	109.90	199.00

Table 2. Estimates of the Parameters and Conjectural Variation with the Static Model for the U.S. Beef Packing Industry by GMM

Parameter	Variable	Estimate	S. E.	t-Statistic	p-Value
Conjectural Variation					
Φ	H	-0.6838	0.0305	-22.45	<.0001
Supply Function					
γ_0	Constant	1.0582	0.0348	30.41	<.0001
ε_S	W_1	0.0069	0.0004	17.53	<.0001
γ_1	P^{corn}	0.0178	0.0105	1.69	0.0922
γ_2	$P^{sorghum}$	-0.0126	0.0044	-2.84	0.0049
γ_3	P^{calves}	-0.0057	0.0003	-21.01	<.0001
γ_4	P^{fuel}	-0.1260	0.0104	-12.12	<.0001
Demand Equation					
δ_0	Constant	0.4892	0.0355	13.79	<.0001
ε_d^r	P	-0.0020	0.0001	-25.06	<.0001
δ_1	P^{pork}	0.0020	0.0002	9.88	<.0001
δ_2	$P^{chicken}$	-0.0014	0.0002	-8.02	<.0001
δ_3	$INCOME$	0.0305	0.0018	30.02	<.0001
Cost Function					
α_{ll}	$(v_l v_l)^{1/2}$	-11.9073	0.1787	-66.64	<.0001
α_{cc}	$(v_c v_c)^{1/2}$	-10.5866	0.1688	-62.72	<.0001
α_{mm}	$(v_m v_m)^{1/2}$	-11.0806	0.1705	-64.98	<.0001
α_{lc}	$(v_l v_c)^{1/2}$	6.2723	0.0987	63.57	<.0001
α_{cm}	$(v_c v_m)^{1/2}$	4.4186	0.0652	67.82	<.0001
α_{ml}	$(v_m v_l)^{1/2}$	7.0132	0.1041	67.39	<.0001
β_l	v_l	-0.8583	0.0230	-37.27	<.0001
β_c	v_c	-0.4366	0.0116	-23.75	<.0001
β_m	v_m	0.4225	0.0227	18.58	<.0001

Table 3. Conjectural Elasticity and Market Power for the U.S. Beef Packing Industry

Marginal Effects	Estimate	S.E.
Conjectural Elasticity (Φ^*)	0.0440	0.0042
Market Power in Retail Market (L^{retail})	0.1041	0.0082
Market Power in Cash Market (L^{cash})	0.0946	0.0110
Market Power in Captive Supply Market ($L^{captive}$)	0.0294	0.0034

Note: All estimates are statistical significant at the 5% significance level.

Table 4. Marginal Effects of Market Concentration on Market Power and Cost Efficiency with Static Model for the U.S. Beef Packing Industry from 1990 to 2006

Oligopoly		Oligopsony				Cost Efficiency		Total Effect	
		Cash Market		Captive Market					
Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
155.68	12.32	45.91	5.34	14.27	1.66	-446.98	12.27	-231.12	9.82

Note: All estimates are statistical significant at the 5% significance level.

Table 5. Estimates of the Parameters and Conjectural Variation with the Dynamic Model for the U.S. Beef Packing Industry by GMM

Parameter	Variable	Estimate	S. E.	t-Statistic	p-Value
Conjectural Variation					
c_0	Constant	0.6105	0.0977	6.25	<.0001
c_1	H	-0.0199	0.0013	-3.54	<.0001
c_2	CR	0.0002	0.0002	-10.51	0.3835
Supply Function					
γ_0	Constant	1.0539	0.0436	24.16	<.0001
ε_S	W_1	0.0068	0.0006	10.98	<.0001
γ_1	P^{corn}	0.0223	0.0116	1.92	0.0562
γ_2	$P^{sorghum}$	-0.0127	0.0051	-2.52	0.0125
γ_3	P^{calves}	-0.0057	0.0002	-18.96	<.0001
γ_4	P^{fuel}	-0.1297	0.0112	-11.61	<.0001
Demand Equation					
δ_0	Constant	0.5050	0.0624	8.09	<.0001
ε_d^r	P	-0.0021	0.0002	-12.28	<.0001
δ_1	P^{pork}	0.0020	0.0003	7.37	<.0001
δ_2	$P^{chicken}$	-0.0014	0.0002	-6.15	<.0001
δ_3	$INCOME$	0.0301	0.0013	23.89	<.0001
Cost Function					
α_{ll}	$(v_l v_l)^{1/2}$	-21.6736	0.2860	-75.78	<.0001
α_{cc}	$(v_c v_c)^{1/2}$	-11.2807	0.1585	-71.15	<.0001
α_{mm}	$(v_m v_m)^{1/2}$	-19.5716	0.2675	-73.16	<.0001
α_{lc}	$(v_l v_c)^{1/2}$	6.7053	0.0953	70.34	<.0001
α_{cm}	$(v_c v_m)^{1/2}$	4.4467	0.0575	77.30	<.0001
α_{ml}	$(v_m v_l)^{1/2}$	15.8728	0.2118	74.94	<.0001
β_l	v_l	-0.6734	0.0266	-25.36	<.0001
β_c	v_c	-0.0536	0.0114	-4.71	<.0001
β_m	v_m	0.4167	0.0315	13.22	<.0001

Table 6. Conjectural Elasticity and Market Power for the U.S. Beef Packing Industry from 1990 to 2006

Year	Conjectural Elasticity		Market Power in Retail Market		Market Power in Cash Market		Market Power in Captive Market	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
1990	0.0503	0.0036	0.1131	0.0058	0.1066	0.0142	0.0200	0.0027
1991	0.0494	0.0038	0.1103	0.0061	0.1040	0.0144	0.0173	0.0024
1992	0.0472	0.0040	0.1053	0.0068	0.0958	0.0140	0.0180	0.0026
1993	0.0422	0.0042	0.0945	0.0073	0.0874	0.0139	0.0133	0.0021
1994	0.0391	0.0043	0.0920	0.0083	0.0891	0.0150	0.0168	0.0028
1995	0.0399	0.0042	0.0945	0.0081	0.0955	0.0157	0.0193	0.0032
1996	0.0388	0.0042	0.0973	0.0086	0.1075	0.0179	0.0233	0.0039
1997	0.0398	0.0042	0.1027	0.0087	0.1001	0.0164	0.0181	0.0030
1998	0.0353	0.0043	0.0911	0.0094	0.0887	0.0159	0.0186	0.0033
1999	0.0347	0.0041	0.0865	0.0090	0.0768	0.0133	0.0267	0.0046
2000	0.0378	0.0040	0.0827	0.0088	0.0714	0.0123	0.0325	0.0056
2001	0.0351	0.0038	0.0815	0.0080	0.0744	0.0120	0.0409	0.0066
2002	0.0352	0.0038	0.0835	0.0082	0.0768	0.0122	0.0444	0.0071
2003	0.0306	0.0042	0.0673	0.0085	0.0597	0.0113	0.0272	0.0052
2004	0.0303	0.0041	0.0658	0.0081	0.0652	0.0122	0.0259	0.0049
2005	0.0339	0.0039	0.0743	0.0075	0.0680	0.0116	0.0251	0.0043
2006	0.0345	0.0038	0.0786	0.0079	0.0697	0.0114	0.0343	0.0056
Ave.	0.0388	0.0040	0.0906	0.0078	0.0855	0.0136	0.0264	0.0042

Note: All estimates are statistical significant at the 5% significance level.

Table 7. Marginal Effects of Market Concentration on Market Power and Cost Efficiency with Dynamic Model for the U.S. Beef Packing Industry from 1990 to 2006

Year	Oligopoly		Oligopsony				Cost Efficiency		Total Effect	
			Cash Market		Captive Market					
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
1990	218.32	11.18	66.55	8.87	12.51	1.67	-204.84	14.77	92.84	12.68
1991	199.19	10.91	60.63	8.39	10.08	1.39	-218.81	14.58	51.10	12.52
1992	171.41	11.05	52.17	7.63	9.08	1.43	-206.69	14.91	26.67	11.94
1993	147.03	11.28	44.75	7.12	6.79	1.08	-183.58	16.18	14.99	11.57
1994	129.95	11.65	39.56	6.67	7.43	1.25	-206.75	16.95	-29.41	12.04
1995	134.82	11.55	41.04	6.76	8.31	1.37	-239.85	18.21	-55.68	12.49
1996	131.07	11.64	39.90	6.65	8.65	1.44	-257.18	18.76	-77.56	13.44
1997	136.65	11.50	41.59	6.83	7.52	1.23	-134.03	19.58	51.73	10.50
1998	116.59	11.97	35.49	6.35	7.44	1.33	-152.30	18.63	7.22	10.07
1999	116.50	12.06	35.46	6.13	12.30	2.13	-182.61	19.82	-18.34	10.06
2000	114.11	12.19	34.73	5.96	15.82	2.72	-180.98	19.91	-16.31	10.36
2001	123.21	12.14	37.50	6.04	20.60	3.32	-195.18	20.83	-13.87	10.60
2002	124.28	12.16	37.83	6.04	21.88	3.49	-234.62	20.52	-50.63	11.53
2003	98.71	12.53	30.05	5.68	13.68	2.59	-217.86	21.35	-75.42	11.20
2004	101.31	12.43	30.84	5.79	12.26	2.30	-196.78	19.90	-52.37	11.64
2005	119.45	12.01	36.36	6.17	13.41	2.28	-184.05	20.44	-14.82	12.06
2006	121.05	12.11	36.85	6.05	18.11	2.98	-181.19	21.65	-5.17	12.55
Ave.	135.57	11.62	41.26	6.61	12.83	2.05	-199.54	18.54	-9.88	11.56

Note: All estimates are statistical significant at the 5% significance level.