ASSESSMENT OF MARKET POWER AND COST EFFICIENCY EFFECTS IN THE U.S. BEEF PACKING INDUSTRY*

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Keywords

beef packing industry, concentration, captive supply, cost efficiency, market power, new empirical industrial organization model

Abstract

This paper examines the simultaneous impacts of horizontal concentration and vertical integration on oligopoly & oligopsony power and cost efficiency in the U.S. beef packing industry, using both static and time varying empirical industrial organization models. Two separate sources of market power are considered: concentration and the captive supply market. Empirical results show the presence of market power in both beef retail and cattle procurement markets, and that the market power exertion in these markets is positively affected by concentration and captive supply, respectively. The results also show that the market power exertion drastically decreases after the implementation of livestock mandatory price reporting. Finally, our study finds that the market power effect is outweighed by the cost efficiency effect due to the increasing concentration and captive supply.

I. Introduction

Concentration and captive supply have been two buzzwords in the literature on market power in the U.S. beef packing industry in recent years. A wave of horizontal and vertical integrations in the beef packing industry began in the late 1970's and has continued into the present market (Azzam 1997). The four-firm concentration ratio based on steer and heifer slaughter increased from 35.7 percent in 1980 to 85.0 percent in 2010, while the ratio based on the boxed beef supply increased from 52.9 percent in 1980 to 84.1 percent in 2006. Most recently, JBS purchased Swift & Co. in 2007 and JBS/Swift acquired Smithfield in 2009 and as a result, the concentration ratio is expected to reach an unprecedentedly high level. As a form of backward integration by packers, the captive supply has also continuously increased over the last two decades.[1] The captive supply ratio as a total of cattle slaughter increased from 20.5 percent in 1988 to 60.6 percent in 2011 (USDAc).

As the horizontal merger continues and, as a result, the industry concentration increases in the beef packing industry, one important and interesting question is whether the cost efficiency that packers have gained from increased concentration outweighs the oligopoly effect. As the captive supply ratio continuously increases, another contentious question is whether the captive supply increases the efficiency by reducing transaction costs and market risk or reduces competition and increases the packers' oligopsony power. However, few studies examine these two issues together in the economic analysis of market power in the U.S. beef processing industry. Our study simultaneously considers these two issues, concentration and captive supply, in a model that can measure oligopoly and oligopsony market powers together. This model estimates the marginal effects of concentration and captive supply on beef and cattle prices to investigate the following question: "Do horizontal and vertical integrations (merger and captive supply) in the beef packing industry increase social welfare by achieving economies of scale and reducing transaction costs?" This model was also developed to examine changing marginal effects over the sample period. With a few exceptions (Appelbaum 1982; Schroeter 1988; Mei and Sun 2008), most of the existing studies in this area are based on

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[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.

the assumption that the conjectural variation is constant throughout the sample period. Therefore, they have limited explanations about how market power changes as the industry structure evolves over time. In the existing literature, conjectural variations typically measure the overall market reaction to an individual firm's changes in output supply and input demand (Dickson 1981).

The objectives of this paper are threefold. First, we estimate the oligopoly and oligopsony market powers for the U.S. beef retail market and cattle procurement market, using the new empirical industrial organization (NEIO) model. In modeling this study, we separated the oligopsony market power for the captive supply market from the oligopsony market power for the cash market. Second, we measure the marginal effects of market power and cost efficiency from increasing concentration and captive supply to examine the effects on the packers' margin. Finally, adopting a time varying model, we estimate the changes in market power that occurred with the changing market structure in the years 1988-2011, using monthly data.

Our results show the presence of market power in both the beef retail and cattle procurement markets. Mergers benefit packers more in the beef retail market than in the cattle procurement market because the marginal effect of the oligopoly market power on the packers' margin is greater than the marginal effect of the oligopsony market power. With the implementation of livestock mandatory price reporting, the powers of oligopoly and oligopsony drastically decrease. Similar to the results of many previous studies, the current study also found that the cost efficiency effect of increasing concentration and captive supply outweigh the market power effect.

II. Literature review

The NEIO framework has been widely used to investigate market power issues in agricultural industries (e.g., Sexton 2000; Sheldon and Sperling 2002; Whitley 2003: Tostao and Chung 2005: Ahn 2006: Chung and Tostao 2012).[2] A few studies

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[2] Perekhozhuk, Glauben, Grings, and Teuber (2016) well summaries many market power researches concerned NEIO model in their recent article, "Approaches and Methods for the Econometric Analysis of Market Power: A Survey and Empirical Comparison," in Journal of Economic Surveys.

have examined market power versus cost efficiency effects from increased concentration in agricultural and food industries. Most studies found that the efficiency gained by a merger offsets consumers' or producers' potential welfare losses (Azzam and Schroeter 1995; Azzam 1997; Tostao and Chung 2005). Azzam and Schroeter (1995) modeled the tradeoff between regional oligopsony power and the cost efficiency that results from consolidation in the beef packing industry. They found that the anticompetitive effects of consolidation are about half the actual cost savings from economies of scale. Azzam (1997) incorporated concentration as an explanatory variable in the margin equation for the cattle input market, to estimate the effect of concentration on market power and the cost-efficiency effect for the U.S. beef packing industry. The study showed that the cost efficiency effect outweighs the oligopsony market power effect. Tostao and Chung (2005) made estimates with an oligopoly model and found that cost efficiency gains dominate potential oligopoly market power effects from increased concentration in the U.S. beef packing industry. Chung and Tostao (2012) build upon the findings of Tostao and Chung (2005) and used a bilateral market power model that takes account of the bilateral oligopoly and oligopsony relationship between processors and retailers. Chung and Tostao (2012) also argued that the overall efficiency effects are larger than market power effects for U.S. beef processors and retailers. However, when Lopez, Azzam, and Espana (2002) applied the framework used earlier by Azzam (1997) to the oligopoly markets of 32 U.S. food industries, they found that market power effects dominate cost efficiency effects in most food industries, which indicates that further increases in concentration would increase the output price.

Numerous studies have examined the captive supply, primarily focusing on the relationship between the captive supply and the cash market price in the cattle procurement market. Many studies report a negative relationship between captive supply and cash market price (Elam 1992; Schroeder et al. 1993; Ward et al. 1996; Ward, Koontz, and Schroeder 1998; Schroeter and Azzam 2004). Many researchers believe that the negative relationship reflects the market power of the packer, as a buyer who uses the captive supply to suppress the cash market price in the cattle procurement market (Schroeder et al. 1993; Ward, Koontz, and Schroeder 1998; Zhang and Sexton 2000). These researchers usually apply an ad-hoc model to investigate the relationship between the captive supply and the cash market price rather than use the theoretically based NEIO model to analyze the effect of the captive supply as a source of market power at the industrial level. One exception is Zheng and Vukina (2009), who developed a NEIO model to investigate the mar-

ket power that packers exercise via the captive supply in the pork packing industry. Tje findings of Zheng and Vukina (2009) suggest that oligopsony market power exists in spot markets, but there is no clear evidence that the captive supply functions as a source of market power. They concluded that the market power is most likely due to concentration.

In the NEIO literature, only a few studies have considered the dynamic nature of competition over time (Appelbaum 1982; Schroeter 1988; Mei and Sun 2008). Appelbaum (1982) estimated the conjectural elasticities for oligopoly market powers of rubber, textile, electrical machinery, and tobacco industries using annual data from 1947 to 1971. Appelbaum's framework included a conjectural elasticity equation specified as a function of a vector of input prices, which allows the market power parameter to vary over time. Schroeter (1988) applied Appelbaum's framework to the beef packing industry for the years 1951 to 1983 and found small but statistically significant oligopoly and oligopsony price distortions. Mei and Sun (2008) specified the parameters of oligopoly and oligopsony market power as a function of a four-firm concentration ratio for the U.S. paper industry and found significant oligopoly and oligopsony market power for the period from 1955 to 2003. A recent study by Crespi, Xia, and Jones (2010) examined the relationship between market power and the cattle cycle. The study concluded that market power is affected by the cattle cycle, and changes in the market power follow the same trend as the cattle cycle.

The present study builds on previous studies in two ways. First, our study considers both concentration and captive supply as a potential source of market power in the U.S. cattle procurement market using the NEIO framework, breaking down the cattle procurement market into cash market and captive supply. Second, we investigate the changes of both oligopoly and oligopsony market powers over the past several decades.

III. The Model

In the existing literature, there have been two general approaches to developing a theoretical framework of conjectural elasticity. 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, the dual approach is used because of the absence of quantity data for output and input at the firm level.

Following Schroeter (1988), beef processors and retailers are integrated in a single "processing-retailing" sector that is allowed to have oligopoly and oligopsony market powers simultaneously. A beef processing-retailing industry consists of N firms converting a single farm input, cattle, into a final output, beef. As discussed above, this study considers two procurement channels, cash market and captive supply. The captive supply for each period is given because the captive supply is determined before a 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. A competitive market is assumed when farmers sell their cattle to packers, i.e. farmers are price takers. Each firm's processing technology is characterized by fixed proportions of farm input and output (Schroeter 1988; Azzam 1997). The conversion of farm input into output requires non-farm inputs that are purchased in competitive markets. Each "processing-retailing" firm is not necessarily a price-taker, neither in the cattle procurement market nor in the beef retail market.

Profit, π_i, for the ith "processing-retailing" firm (for $i = 1, 2, ..., N$) is maximized as:

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

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 ith firm's beef product or cattle input from the cash market, q_{2i} is the ith firm's beef product or cattle input from the captive supply, $q_i = q_{1i} + q_{2i}$ is the ith firm's total beef product or total cattle input, $Q = \sum_i^N q_i$ is the industry's total beef product or total cattle input, $Q_1 = \sum_i^N q_{1i}$

and $Q_2 = \sum_{i}^{N} q_{2i}$ are the industry's beef product or cattle input from cash market and captive supply, respectively, $C_i(q_i, v)$ is the processing cost function for the ith firm, and v is a vector of prices of non-farm inputs. The first order condition for profit maximization is:

$$(2) \qquad \frac{\partial \pi_i}{\partial q_{1i}} = P - W_1 + \left(\frac{\partial P}{\partial Q} \frac{\partial Q}{\partial q_{1i}} \right)(q_{1i} + q_{2i}) - \left(\frac{\partial W_1}{\partial Q_1} \frac{\partial Q_1}{\partial q_{1i}} \right) q_{1i}$$

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

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

$$(3) \qquad M_i = -\frac{(1 + \phi_i)}{\epsilon_d} s_i + \frac{(1 + \phi_i)}{\epsilon_s} s_i + \frac{\eta(1 + \phi_i)}{\epsilon_s} \frac{q_{2i}}{q_{1i}} s_i + c_i(q_i, v),$$

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

Following Azzam (1997), the ith firm's cost function is assumed to take the generalized Leontief form:

$$(4) \qquad C_i(q_i, v) = q_i \sum_{k} \sum_{j} \alpha_{kj} (v_k v_j)^{1/2} + (q_i)^2 \sum_{j} \beta_j v_j,$$

where v_j and v_k are the input price of labor, capital, and material. When equation (3) is rewritten using a generalized Leontief cost function specified in equation (4), it becomes:

(5) $\quad M_i = -\dfrac{(1+\phi_i)}{\epsilon_d}s_i + \dfrac{(1+\phi_i)}{\epsilon_s}s_i + \dfrac{\eta(1+\phi_i)}{\epsilon_s}\dfrac{q_{2i}}{q_{1i}}s_i$

$$+ \sum_k\sum_j\alpha_{ki}(v_kv_j)^{1/2} + 2q_i\sum_j\beta_jv_j \qquad .$$

Multiplying (5) by each firm's market share, s_i, and summing across all n firms in the industry yields:

(6) $\quad \displaystyle\sum_i^n s_iM_i = -\sum_i^n s_i\dfrac{(1+\phi_i)}{\epsilon_d}s_i + \sum_i^n s_i\dfrac{(1+\phi_i)}{\epsilon_s}s_i + \sum_i^n s_i\dfrac{\eta(1+\phi_i)}{\epsilon_s}\dfrac{q_{2i}}{q_{1i}}s_i.$

$$+ \sum_i^n s_i\Big(\sum_k\sum_j\alpha_{ki}(v_kv_j)^{1/2} + 2q_i\sum_j\beta_jv_j\Big)$$

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

(7) $\quad M = -\dfrac{(1+\Phi)H}{\epsilon_d} + \dfrac{(1+\Phi)H}{\epsilon_s} + \dfrac{\eta(1+\phi_i)H}{\epsilon_s}\dfrac{Q_2}{Q_1}$

$$+ \sum_k\sum_j\alpha_{ki}(v_kv_j)^{1/2} + 2HQ\sum_j\beta_jv_j \qquad ,$$

where M is the market-share weighted average margin for the beef packing industry, $H = \sum_i(s_i)^2$ is the Herfindahl-Hirschman Index in the retail beef market and in the cattle procurement market, $\Phi = \sum_i(q_{1i})^2\phi_i/\sum_i(q_{1i})^2$ is the market-share weighted average conjectural variation in the retail output market and in the farm input market.

In equation (7), the first three terms on the right-hand side capture the mark-up through the beef retail market, the mark-down through the cash cattle procurement, and the mark-down through the captive supply, respectively. The fourth term is the market-share weighted average marginal cost for the integrated processing/retailing sector. The value of $\Phi = -1$ means that no mark-up or mark-down occurs. In this case all firms are price-takers in the beef retail market and in the cattle procurement market, and therefore the output price or the farm-input price is unchanged by market power. The value of $\Phi = 0$ implies Cournot monopoly and monopsony. In the case of noncompetitive products, concentration affects all mark-up, mark-down, and marginal costs in equation (7). Appelbaum (1982) de-

fines 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 as $E_d = \epsilon_d P$ and $E_s = \epsilon_s W_1$ respectively. Then, the degree of the market power is defined by Lerner indices. The industry oligopoly market power is defined by $L^{retail} = -\Phi^*/E_d$, and the oligopsony market power for the cash market and the captive supply are defined by $L^{cash} = \Phi^*/E_s$ and $L^{captive} = \eta(Q_2/Q_1)\Phi^*/E_s$ respectively (Lopez, Azzam, and Espana 2002). 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).

We can separate the marginal effects of the packers' margin from an increase of concentration in the processing/retailing industry, into two parts: market power effects and cost efficiency effects. Differentiating equation (7) with respect to the Herfindahl-Hirschman Index, H results in:

$$(8) \qquad \frac{\partial M}{\partial H} = -\frac{(1+\Phi)}{\epsilon_d} + \frac{(1+\Phi)}{\epsilon_s} + \frac{\eta(1+\phi_i)}{\epsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j.$$

The first three terms on the right-hand side of equation (8) capture the market power effects, while the fourth term captures the cost savings for the beef packing industry (Azzam 1997; Lopez, Azzam, and Espana 2002).

The marginal effects of the captive supply on the packers' margin can also be derived by differentiating equation (7) with respect to the captive supply, Q_2, as:

$$(9) \qquad \frac{\partial M}{\partial Q_2} = \frac{\eta(1+\Phi)H}{\epsilon_s}\frac{1}{Q_1} + 2H\sum_j \beta_j v_j.$$

The first term on the right-hand side of equation (9) captures the market power effect, and the second term captures the cost savings gained by changing the captive supply.

This study examines three main questions concerning the presence of market power in the beef retailing and cattle procurement markets and its impact on

the packers' margin. First, we test whether an oligopoly market power exists from the beef retailers and the two sources of oligopsony market powers (one from the cash market and the other from the captive supply market) in the U.S. beef packing industry. By testing the hypothesis for estimates of market power parameters, we can determine whether or not the packers exert market power in the beef retail market, the cash cattle procurement market, and the captive supply market. Second, using estimated parameters, we compute the cost efficiency and market power effects to judged whether one outweighs the other. If the cost efficiency effects outweigh the market power effects, then one can conclude that the recently increased concentration and captive supply in the U.S. beef packing industry led to increased social welfare. Finally, we investigate how degrees of oligopoly and oligopsony power change over time.

IV. Estimation Methods

For complete identification, the price equation (equation (7)) needs to be estimated simultaneously with equations of three non-farm input demands, the farm input (cattle) supply, the retail output (beef) demand, and the captive supply price. Non-farm input demands are obtained by applying the Shephard's lemma to the industry level processing cost (equation (4)) as:

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

which can be rearranged as:

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

where X_j is derived non-farm input demand at the industry level for labor, capital, and material, and e_j is the error term for the non-farm input demand function.

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

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

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

where, as defined previously, ϵ_s and ϵ_d are the semi-price elasticity of supply for cash market and the semi-price elasticity of demand, respectively; P^{corn}, $P^{sorghum}$, P^{calf}, and P^{fuel} are corn, sorghum, calf, and fuel prices, respectively; P^{pork} and $P^{chicken}$ are retail prices of pork and chicken prices respectively; I is income, and e_s and e_d are error terms for supply and demand equations, respectively.

Finally, the captive supply price (W_2) is specified as a function of the cash market price (W_1), the quantity of cattle procured through the captive supply (Q_2), the total quantity of procured cattle (Q) and the linear and squared time trend terms ($time$) and ($time^2$). The empirical model for the captive supply price can then be expressed as:

(14) $W_2 = \sigma_0 + \eta W_1 + \sigma_1 Q_2 + \sigma_2 Q + \sigma_3 time + \sigma_4 time^2 + e_w,$

where e_w is the error term. The cash market price W_1 is included as an independent variable because the price of cattle through the captive supply (marketing agreement and forward contract) is calculated using various formulas that are closely tied to the cash market price (Schroeter and Azzam 2004). Data for the captive supply price is not available from 1988 to 2002, which was before the implementation of livestock mandatory price reporting. Therefore, equation (14) is separately estimated to find the value, η, with the monthly data from 2003 to 2011. The estimation results show that η is 0.8458, and is significant at the 1% significance level.[3] Zheng and Vukina (2009) estimated the elasticity of the captive

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[3] In estimating equation (14), the RESET test is conducted, and results indicate that the linear model specified in equation (14) is appropriate with the power 2, 3, and 4 at the 5% significance level. However, the Durbin-Watson test suggests an autocorrelation problem in this model. Therefore, a GLS procedure is implemented to estimate the parameters. Results show: σ_0 = 13.1283, η = 0.8458, σ_1 = 4.0172, σ_2 = -3.2483, σ_3 = 0.0637, and σ_4 = -0.0005. σ_0, η , σ_2, and σ_3 are significant at the 5% significance level while   and σ_4 are significant at the 10% significance level.

supply price with respect to the cash market price, $\frac{\partial W_2}{\partial W_1} \frac{W_1}{W_2}$, rather than $\frac{\partial W_2}{\partial W_1}$ in a similar equation for the U.S. pork industry. Zheng and Vukina (2009) estimated the elasticity to be 0.7835 while the corresponding elasticity in our study is 0.8887.

1. Static Estimation

Equations (7), (11), (12), and (13), which constitute a system of six equations in total, are simultaneously estimated while equation (14) is separately estimated due to the data limitation described earlier (the captive supply price data is not available from 1988 to 2002). To overcome potential endogeneity problems in the simultaneous equation estimations, an instrumental variable estimator called the generalized method of moments (GMM) was employed in this study. We also chose to use GMM because the Breushch-Godfrey Test for autocorrelation (Breusch 1978; Godfrey 1978) rejects the null hypothesis of no first-order autocorrelation on each equation. The seventeen instrumental variables included in the equation are the Herfindahl-Hirschman Index for the steer and heifer slaughter, the squared Herfindahl-Hirschman Index, the four-firm concentration ratio for cattle procurement market, the squared four-firm concentration ratio, the cattle cash price, the cattle price, the four-firm captive supply ratio, the labor price, capital price, material price, corn price, sorghum price, calves price, fuel price, pork price, chicken price, income, and time.

2. Time-varying Estimation

The static econometric specification discussed in the previous section can estimate only one constant market conduct parameter, Φ, for the entire sample period. The static model cannot allow possible changes in the market conduct parameter over time. However, as suggested in a few previous studies (Schroeter 1988; Azzam 1997; Lopez, Azzam, and Espana 2002; Mei and Sun 2008), the market conduct parameter can vary over time as the market environment (for example, market con-

centration) changes.[4] Recent increases in the concentration ratio (particularly due to JBS/Swift merger) and the captive supply ratio can affect changes in the market conduct parameter. To accommodate the potential varying nature of the market conduct parameter over the sample period, the market conduct parameter is modeled as a function of the Herfindahl-Hirschman Index, H, and the captive supply, Q_2, as:

$$(15) \quad \Phi = c_0 + c_1 H + c_2 Q_2.$$

Equation (15) allows the conjectural variation parameter, Φ, to vary in response to changes in H and Q_2 over time. Then equation (7) can be rewritten as:

$$(16) \quad M = -\frac{(1 + c_0 + c_1 H + c_2 Q_2)H}{\epsilon_d} + \frac{(1 + c_0 + c_1 H + c_2 Q_2)H}{\epsilon_s} + \frac{\eta(1 + c_0 + c_1 H + c_2 Q_2)H}{\epsilon_s}\frac{Q_2}{Q_1} + \sum_k \sum_j \alpha_{kj}(v_k v_j)^{1/2} + 2HQ\sum_j \beta_j v_j$$

Differentiating equation (16) with respect to H and Q_2 yields:

$$(17) \quad \frac{\partial M}{\partial H} = -\frac{(1 + c_0 + 2c_1 H + c_2 Q_2)}{\epsilon_d} + \frac{(1 + c_0 + 2c_1 H + c_2 Q_2)}{\epsilon_s} + \frac{\eta(1 + c_0 + 2c_1 H + c_2 Q_2)}{\epsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j$$

$$(18) \quad \frac{\partial M}{\partial Q_2} = -\frac{c_2 H}{\epsilon_d} + \frac{c_2 H}{\epsilon_s} + \frac{\eta(1 + c_0 + c_1 H + 2c_2 Q_2)H}{\epsilon_s}\frac{1}{Q_1} + 2H\sum_j \beta_j v_j.$$

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[4] Azzam (1997) and Lopez, Azzam, and Espana (2002) use time varying models to specify the conjectural variation parameter as a function of the Herfindahl-Hirschman Index. However both studies fail to reject the null hypothesis that the conjecture variation parameter is a constant. Mei and Sun (2008) modeled the conjectural variation parameter as a function of the four-firm concentration ratio and average mill capacity for the U.S. paper industry. Appelbaum (1982) modeled the conjectural elasticity as a function of labor input price, capital input price, and material input price. Schroeter (1988) also modeled the time varying parameter of conjectural variation as a function of labor input price, capital input price, and time trend for the U.S. beef packing industry.

Now, equations (17) and (18) can show changes in the effects of the industry concentration and captive supply on packers' margins over time, while equations (8) and (9) can measure the impact only on average for the sample period. Unlike equation (9), equation (18) can decompose the impact of the change in the captive supply on the packers' margin into four parts: the mark-up in the retail market, mark-down due to cash market, mark-down due to captive supply, and cost saving.

Equations (11), (12), (13), and (16) are estimated for the time varying model. The time varying conjectural variation elasticity, Φ^*, and Lerner indices, L^{retail}, L^{cash}, and $L^{captive}$ can be estimated with estimates of c_i and supply and demand price elasticities. The time varying model is also estimated using the GMM procedure in SAS 9.2.

V. Data

The main data set used in this study comes from the Agricultural Marketing Service (AMS), the National Agricultural Statistic Service (NASS), the Grain Inspection, Packers and Stockyards Administration (GIPSA), and the Economic Research Service (ERS) of the United States Department of Agriculture (USDA). Monthly data series for 1988 to 2011 are compiled for all variables listed following the empirical procedure.

The cattle slaughter quantity in total live weight, which is used as the total beef production and the total cattle input supply (due to the fixed proportion assumption) in this study, was compiled from the Livestock Slaughter Annual Summary of NASS (USDAd). The cattle price data from the cash market was obtained from several long-term fed cattle price data of the Mandatory Price Report (MPR) of AMS, which has reported the Nebraska direct fed steer price (USDAa). The retail price of beef was provided by ERS, USDA (USDAb). The weighted captive supply price was combined from MPR of AMS, but the captive supply price data was only available from 2003. The Herfindahl-Hirschman Index, the four-firm concentration ratio, and the four-firm captive supply ratio for the steer and heifer slaughter were compiled from annual reports from the Packers and Stockyards Statistical Reports (1998-2006) GIPSA (USDAc).

For beef demand and cattle supply equations, the retail prices of beef and pork, wholesale price of chicken, and corn and calf prices were obtained from ERS

(USDAb). The fuel oil number 2 prices were obtained from the Consumer Price Index Data base of the Bureau of Labor Statistics (BLS), U. S. Department of Labor (USDL). The per capita income data are from the econstats site (http://www.econstats.com). The consumer price index for meat and the producer price index for farm products are from BLS (USDL). These two price indices were used as price deflators for beef prices, cattle prices, and other farm product prices respectively.

TABLE 1. Descriptive Statistics of Variables Used in the Empirical Estimation
(1988.1-2011.12, N=288)

Variable	Mean	S. D.	Minimum	Maximum
Herfindahl Hirschman index for steer and heifer slaughter	0.1893	0.0173	0.1589	0.2261
Cattle slaughter weight (bil./lbs)	3.811	0.2714	2.8087	4.1485
Retail price of beef ($/cwt)	338.11	69.00	238.80	501.60
Cash market price ($/cwt)	78.15	12.94	58.33	123.50
Captive supply price ($/cwt)	83.45	11.79	59.96	117.09
4 firm concentration ratio	78.98	3.89	69.70	85.00
4 firm captive supply ratio	33.15	13.08	14.10	60.60
Price of corn ($/bushel)	2.74	1.03	1.52	6.88
Price of sorghum ($/bushel)	2.59	1.04	1.41	6.55
Price of calves ($/cwt)	104.92	20.59	55.40	157.00
Price of fuel oil #2 ($/gallon)	1.61	0.92	0.79	4.65
Retail price of pork ($/cwt)	252.61	39.45	187.37	356.10
Retail price of chicken ($/cwt)	156.82	13.38	117.22	185.68
Per capita income (thousand $)	12.69	1.55	10.24	15.32
Labor productivity (2005=100)	90.09	5.66	80.94	100.00
Price of labor (2005=100)	82.37	17.44	56.99	110.03
Capital productivity (2005=100)	99.12	2.85	93.68	104.67
Price of capital (2005=100)	100.22	19.77	65.47	150.82
Material productivity (2005=100)	102.36	2.76	97.94	108.54
Price of material (2005=100)	95.97	16.19	79.13	141.02
PPI for farm product (2005=100)	89.55	14.75	66.07	141.23
CPI for meat (2005=100)	87.16	16.35	59.87	123.88

For the marginal cost and non-farm input demand equations, the price index and the productivity index of labor for the U.S. animal slaughtering and processing industries were obtained from the Industry Productivity and Costs Database of BLS (USDL). The price index and the productivity index of capital and material for U.S. food and other industries were obtained from the Major Sector Multifactor Productivity Index Database of BLS (USDL). The definitions and descriptive statistics of these variables are presented in Table 1.

VI. Empirical Results

Table 2 presents the estimation results of the static and time varying models. For the static model, all 20 parameter estimates are statistically significant at the 5% significance level except for the parameter estimate of the sorghum price. The coefficient of conjectural variation, $\Phi = -0.8980$, was tested for pure monopoly or pure monopsony ($\Phi = 0$) and also for perfect competition ($\Phi = -1$). Both null hypotheses were rejected at the 1% level, indicating that oligopoly and oligopsony conducts exist in the U.S. beef packing industry. The semi-price elasticities of supply and demand were 0.0078 and -0.0030, respectively, and showed expected signs. For the time varying model, conjectural variation was specified as a function of the Herfindahl-Hirschman Index and captive supply, which allowed us to estimate changes in conjectural elasticity, Φ^{*}, and market power parameters L^{retail}, L^{cash}, and $L^{captive}$ over time. The magnitude of the parameter estimates and overall fitness are comparable to those from the static GMM estimation. Most of the coefficients including an additional coefficient in the conjectural equations (c_0, c_1, c_2) were significant at the 5% significance level. The coefficient of the Herfindahl-Hirschman Index (c_1) was 0.2456 which was the expected positive value, while the coefficient of captive supply (c_2) was -0.0849, a negative value.[5] The average of the conjectural variation (Φ) from the time varying model was -0.8979, which is comparable to the absolute value of -0.8980 from the static model. The semi-price elasticities of supply and demand from the time varying model were 0.0080 and -0.003 respectively, representing almost no change from the static model.

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[5] The negative coefficient of captive supply quantity may be due to the decreasing margin in the meat packing industry, as the captive supply increased in recent years.

TABLE 2. GMM Estimates of Parameters and Conjectural Variation from Static and Time varying Models for the U.S. Beef Packing Industry

Parameter	Variable	Static Model	Time Varying Model
Conjectural Variation			
Φ, c_0	Constant	-0.8980 (0.0042)**	-0.8451 (0.0130)**
c_1	H		0.2456 (0.0767)**
c_2	Q_2		-0.0849 (0.0028)**
Supply Function			
γ_0	Constant	1.1776 (0.0519)**	1.1817 (0.0617)**
ϵ_s	W_1	0.0078 (0.0002)**	0.0080 (0.0003)**
γ_1	P^{corn}	-0.2219 (0.0251)**	-0.2221 (0.0266)**
γ_2	$P^{sorghum}$	0.0064 (0.0181)	0.0047 (0.0173)
γ_3	P^{calf}	-0.0045 (0.0003)**	-0.0045 (0.0004)**
γ_4	P^{fuel}	-0.1486 (0.0064)**	-0.1485 (0.0068)**
Demand Equation			
δ_0	Constant	0.3819 (0.0766)**	0.3795 (0.0694)**
ϵ_d	P	-0.0030 (0.0002)**	-0.0030 (0.0001)**
δ_1	P^{pork}	0.0004 (0.0001)**	0.0004 (0.0002)**
δ_2	$P^{chicken}$	0.0009 (0.0002)**	0.0009 (0.0002)**
δ_3	I	0.0441 (0.0025)**	0.0443 (0.0026)**
Cost Function			
α_{ll}	v_l	20.1384 (0.2235)**	4.1067 (0.0462)**
α_{cc}	v_c	-5.1667 (0.0661)**	-2.4482 (0.0229)**
α_{mm}	v_m	6.2545 (0.0830)**	3.7525 (0.0184)**
α_{lc}	$(v_l v_c)^{1/2}$	-2.6272 (0.0460)**	1.7974 (0.0217)**
α_{cm}	$(v_c v_m)^{1/2}$	5.8364 (0.0587)**	0.0671 (0.0059)**
α_{ml}	$(v_m v_l)^{1/2}$	-13.1176 (0.1453)**	-4.0361 (0.0248)**
β_l	v_l	-2.2051 (0.0333)**	-0.7970 (0.0261)**
β_c	v_c	1.7005 (0.0175)**	0.6991 (0.0138)**
β_m	v_m	-0.0179 (0.0134)**	-0.1645 (0.0111)**

Notes: Parentheses are approximate standard errors.
    * significant at the 10% significance level.
    ** significant at the 5% significance level.

Using the estimates of the parameters reported in Table 2, we calculated the conjectural elasticity, Φ^*, and degrees of market power represented by the Lerner indices (oligopoly power, L^{retail}, oligopsony power from cash market, L^{cash}, and oligopsony power from captive supply market, $L^{captive}$): the results are presented in Table 3 for both static and time varying models. From the static model, the conjectural elasticity was 0.0193, while the degree of oligopoly power (L^{retail}), the oligopsony power from cash market (L^{cash}), and the oligopsony power from captive supply ($L^{captive}$) were 0.0399, 0.0270, and 0.0128.[6] They were all significant at the 1% significance level. We calculated the market power parameters and standard errors using the delta method. The Lerner index, 0.0399, from the retail market indicated a 3.99% mark-up in the beef price, while the Lerner indices, 0.0270 and 0.0128, from the cattle procurement market suggested 2.70% and 1.28% mark-downs in the cattle price, respectively.

For the time varying model, the average value of the varying conjectural elasticities was 0.0193, while the average values of L^{retail}, L^{cash}, and $L^{captive}$ were 0.0400, 0.0268, and 0.0129, respectively. All these estimates were significant at the 1% significance level. The statistically significant estimates of Lerner indices implied that market power exists in both beef retail and cattle procurement markets. The market power in the cattle procurement market, the summation of Lerner indices from the captive supply and cash markets, had values comparable to the retail market from both the static and time varying models. These results are consistent with the findings of Tostao and Chung (2005) and Chung and Tostao (2012).

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

| Market Power	Static Model	Dynamic Model
Conjectural Elasticity (Φ^*)	0.0193 (0.0008)	0.0193 (0.0008)
Oligopoly Power in Retail Market (L^{retail})	0.0399 (0.0012)	0.0400 (0.0014)
Oligopsony Power in Cash Market (L^{cash})	0.0270 (0.0014)	0.0268 (0.0018)
Oligopsony Power in Captive Supply ($L^{captive}$)	0.0128 (0.0007)	0.0129 (0.0008)

Note: Parentheses are standard errors.
All estimates are statistical significant at the 1% significance level.

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[6] The boundaries of each Lerner index were estimated based on, $0 < L < 1/\left|E_{d(s)}\right|$. They are $0 < L^{retail} < 2.0704$, $0 < L^{cash} < 1.4245$, and $0 < L^{captive} < 0.6747$, respectively. The minimum value, 0, leads to perfect competition, and the maximum values lead to pure monopoly or pure monopsony.

Figure 1 graphically illustrates the dynamic changes in the market power of the U.S. beef retailers and processors industry from 1988 to 2011. In the years 1988-2011, the maximum value of oligopoly power was 0.0647 in 1993 and the minimum value was 0.0055 in 2011. The maximum value of oligopsony power was 0.0521 in 1998, and the minimum value was 0.0111 in 2011. Figure 1 demonstrates that the oligopoly power and oligopsony power drastically decreased after 1998. The discussion of livestock mandatory price reporting in the cattle prices and quantities of packers began in 1999 and the law was implemented in 2001, so the market power changes in the beef packing industry obviously reflect these institutional changes over the period. After the implementation of livestock mandatory price reporting in 2001, the market power increased again over several years. The oligopoly power and oligopsony power in the cash market had the same trends while the oligopsony power in the captive supply was relatively steady and increasing. The oligopsony power from the cash market has always been larger than the market power from the captive supply market. However, in recent years the market power caused by the captive supply has been increasing while the market power from the cash market has been decreasing. The overall trend of oligopsony power was dominated by the market power from the cash market until 2009. The increase in market power after 2008 is thought to have been caused by the merger of JBS/Swift & Co. in 2007 and JBS/Smithfield in 2009.

Figure 1. Changes in the Market Power of the U.S. Beef Packing Industry (1988-2011)
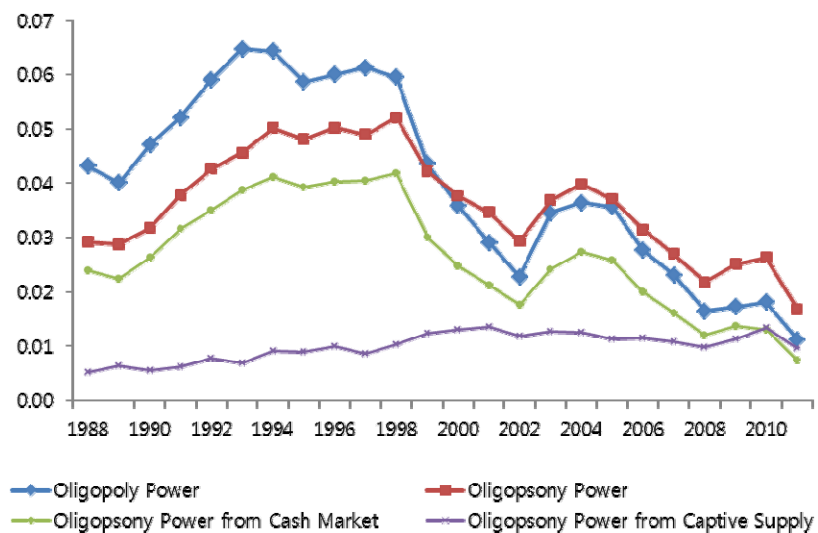
We calculated the marginal effects of the market concentration on packers' margins (retail price minus the farm price) using equation (8) for the static model and equation (17) for the time varying model. The results are reported in Table 4. As discussed previously, we separated the marginal effects into market power and efficiency effects. The market power effects were further separated into three parts: effects from oligopoly, oligopsony from the cash market, and oligopsony from the captive supply market. From the static model, the oligopoly effect, the oligopsony effect from cash market and captive supply, and the cost efficiency effect were 33.92, 12.83, 6.07, and –90.00, respectively. The total effect was – 37.17, which indicates that the cost efficiency effect outweighs the market power effect. The estimated effects were all statistically significant at the 1% significance level, based on standard errors calculated with the delta method. The results suggest that if the Herfindahl-Hirschman Index increases by 1, then the packers 'margin will increase about $0.34/lbs by the oligopoly effect, $0.13/lbs by the oligopsony effect from cash market, and $0.06/lbs by the oligopsony effect from captive supply, respectively and will decrease by $0.90/lbs by the cost efficiency effect, and overall, the margin will decrease by $0.37/lbs. This result is consistent with the common belief that packers pursue mergers to increase their efficiency, but it can also reinforce their potential bargaining position in the market with mergers and integration.

TABLE 4. Marginal Effects of Market Concentration on the Margin for the U.S. Beef Packing Industry from 1988 to 2011

Marginal Effect	Static Model (cents/lbs)	Time Varying Model (cents/lbs)
Oligopoly	33.92 (1.0201)	49.52 (4.8405)
Oligopsony Cash Market	12.83 (0.6922)	18.57 (1.8152)
Oligopsony Captive Market	6.07 (0.3279)	8.80 (0.8598)
Cost Efficiency	-90.00 (5.0870)	-79.24 (0.0047)
Total Effect	-37.17 (5.0870)	-2.35 (7.5155)

Note: Parentheses are standard errors.
       All estimates are statistical significant at the 1% significance level.

Using the time varying model, we calculated the oligopoly effect, the oligopsony effect from cash and captive supply markets, the cost efficiency effect, and the total effect for each year. The average values of these effects were 49.52, 18.57, 8.80, -79.24, and – 2.35, respectively. They were also statistically significant

at the 1% significance level. We also calculated the standard errors with the delta method. The marginal effect estimates of market powers were bigger in absolute value that those of the static model, while the marginal effect estimates of cost efficiency were smaller than those of the static model. The results from the two models suggest that a merger is more effective in the beef retail market than in the cattle procurement market for an integrated industry of beef retailing and processing because as the industry concentration increases, the oligopoly power effect is bigger than the oligopsony power effect. The results also show that the cost efficiency effect overwhelmingly dominates the market power effects in both static and time varying models. This outcome is consistent with the findings of Azzam and Schroeter (1995), Azzam (1997), Sexton (2000), Tostao and Chung (2005), and Chung and Tostao (2012), but contradicts to those of Lopez, Azzam, and Espana (2002).

Table 5 shows the calculations of the marginal effects of the captive supply on the packers' margin. The oligopsony and cost efficiency were 0.89 and –4.90, respectively, which led to the total net effect of –4.01 from the static model. The results indicate that if the captive supply increases by 100,000 cwt, then the packers' margin will increase by 0.89 cent/lbs due to the oligopsony effect and decrease by 4.9 cent/lbs due to the cost efficiency effect, which will produce 4.01 cent/lbs in total net effect. For the time varying model, the average values for the oligopoly effect, the oligopsony effects from cash market and captive supply, the cost efficiency effect, and the total net effect were –5.36, -2.01, 0.02, -4.31, and –11.65, respectively. These values were statistically significant at the 1% significance level (based on standard errors from the delta method). These results suggest that increasing the captive supply expands oligopsony power in the captive supply market while shrinking the oligopoly power and oligopsony power in the cash market. This result is opposite of what we found from the static model. This difference is believed to be caused by the specification of conjectural variation equation and the estimated coefficient of captive supply (c_2) in this equation.

TABLE 5.   Marginal Effects of Captive Supply on the Margin for the U.S. Beef Packing Industry from 1988 to 2011

Marginal Effect	Static Model (cents/lbs)	Time Varying Model (cents/lbs)
Oligopoly	-	-5.36 (0.1735)
Oligopsony Cash Market	-	-2.01 (0.0651)
Oligopsony Captive Market	0.89 (0.0480)	0.02 (0.0283)
Cost Efficiency	-4.90 (0.2767)	-4.31 (0.0002)
Total Effect	-4.01 (0.2865)	-11.65 (0.2669)

Note: Parentheses are standard errors.
     All estimates are statistical significant at the 1% significance level.

VII. Conclusions

This paper contributes to the literature regarding the market power of the U.S. beef packing industry in two ways. First, our study considers both concentration and captive supply as potential sources of market power in the U.S. cattle procurement market using the NEIO framework. Second, we investigate the dynamic changes in both oligopoly and oligopsony powers in the recent two decades. Empirical results from both static and time varying models showed the presence of market power in both beef retail and cattle procurement markets. Two sources of market power, concentration and captive supply, were included in the framework, and econometric results showed that both had effects on changing the market powers during the period covered by the data. Our findings imply that packers use mergers (i.e., increasing concentration) and captive supply as sources of market power, but mergers play a more significant role in the beef retail market and the cattle procurement market. Additionally packers use captive supply to increase their efficiency rather than increase market power. With the implementation of livestock mandatory price reporting, the powers of oligopoly and oligopsony drastically decreased. Finally, as concentration and captive supply increased, the cost efficiency effect outweighed the market power effect in both static and time varying models. Therefore, we can conclude that the increase of concentration and captive supply in the U.S. beef packing industry corresponds to an increase in social welfare.

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