CONSOLIDATION AND MARKET POWER IN THE

U. S. BEEF PROCESSING INDUSTRY

By

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Submitted to the Faculty of the Graduate College of the Oklahoma State University In partial fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY July, 2006

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PREFACE

This dissertation includes two essays. The first essay is entitled "Horizontal Consolidation in the U.S. Beef Processing Industry: Bone or Bane." This essay separated retailer's potential market power from processor's potential market power. The model was used to estimate the tradeoffs between efficiency effects and market power effects from an increase in concentration in the U.S. beef processing industry. Results showed that processor's market power effects are smaller when retailers are considered separately from processors. Processors potential efficiency gains were also small, but exceeded market power effects slightly. Therefore, further increase in concentration could lead to market power effects greater than the cost saving effects. Results showed the importance of considering processors' potential market power separately from retailers' potential market power in estimating the effects of the increased concentration in the U.S. food industry.

The second essay is entitled "Integrating Auction Theory with Traditional Measures of Market Power." The objective this essay was to determine the relationship between auction and new empirical industrial organization (NEIO) models of market power, and examine their relative accuracies. A theoretical model showed that neither NEIO nor auction models are fully describe market power in cattle procurement markets. Using data from an experimental cattle market, we show that both theories yield estimates of price markdown close to actual. Results from non-nested hypothesis tests

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indicated that either theory did not sufficiently explain price markdown behavior in the cattle procurement market. Theoretical results were consistent with empirical results.

ACKNOWLEDGEMENT

I wish to express my sincere appreciation to my academic adviser Dr. Chanjin Chung for his intelligent supervision and invaluable guidance and encouragement throughout my Ph.D. program at Oklahoma State University. I also wish to thank all members of my academic committee, Dr. Wade Brorsen, Dr. Clement Ward, and Dr. William Warde for their helpful advice and invaluable comments during the preparation of this dissertation. I am also indebted to Dr. Derrell Peel for helping me collect data for the second essay.

My appreciation is extended to the Department of Agricultural Economics for providing a research opportunity and financial support for my Ph.D. program. Friendly faculty and staff in the department have contributed to my academic success.

I am thankful to my late mom Rosa, and my dad José for their support, encouragement and love. Mom and dad gave me the greatest lessons in my life. My wife Angelina and my son Emilson have been my continuous source of inspiration and love. Working on my Ph.D. was a lot easier with Angelina and Emilson on my side. Kanimambo por tudo.

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ESSAY I

HORIZONTAL CONSOLIDATION IN THE UNITED STATES BEEF PROCESSING INDUSTRY: BOON OR BANE?

Introduction

As agricultural food processing and retailing industries become increasingly concentrated, there have been numerous studies examining the impact of changes in market structure on social welfare (Schroeter, 1988; Azzam, 1997; Sexton 2000; Paul 2001; Lopez, Azzam, and Espana, 2002). An issue of increasing concern is whether cost efficiency gains from increased industry concentration exceeded potential market power effects.

With the exception of Lopez, Azzam, and Espana (2002), most studies in the industrial organization literature found that processors have oligopoly and/or oligopsony market power, and cost savings from the increased concentration generate cost savings that offset potential market power (Azzam and Schroeter, 1995; Azzam, 1997; Paul, 2001). However, many previous studies did not account for retailers' potential market power separately from processors' potential market power. Rather, these studies focused on processors alone, ignoring retailer's potential to exercise market power. Yet, retailers tend to be larger than processors and have a bigger influence on food distribution and

prices (Choi, 1996; Digal and Ahmadi-Esfahani, 2002). Unlike processors, retailers do not have to deal with perishability that leads to inelastic supply. Inelastic supply at the processors' level increases retailers' potential to exercise market power on processors. Retailers' charge of promotional and slotting fees to manufactures is also potentially anticompetitive (Shaffer, 1991). Thus, ignoring retailers' potential market power in measuring the consequences of increased concentration in food processing could be misleading.

The objective of this study is to separate processors' market power from retailers' market power. The approach relies on pricing rules derived from first-order conditions of firm profit maximization. The new approach is applied to quarterly data from the U. S. beefpacking industry to estimate market power and cost saving effects. Results show that under the assumption that retailers and processors are integrated in a single "processing/retailing" sector, processors' market power effects are not negligible. However, once retailers' market power is allowed separately from processors' power, then processors' apparent market power becomes immaterial. Cost savings from the increased concentration in the U.S. beefpacking industry are only slightly bigger than market power effects. Therefore, further increase in concentration could lead to market power effects greater than the cost saving effects.

Economic Effects of Consolidation

Inspired by Bain's (1951) seminal work, earlier studies examining the effects of the increased concentration in the U.S. beefpacking industry used the structure-conductperformance methodology (SCPM) (Menkhaus, Clair, and Ahmaddaud, 1981; Ward,

1982, 1984; Marion and Geithman, 1995). The SCPM hypothesizes that market structure determines market conduct, and market conduct determines market performance. Typical studies using the SCPM rely on reduced-form regressions of prices and/or accounting profits on measures of concentration. These studies often find that concentration is positively related to firm profits or output prices, and negatively related to farm input prices. The main limitation of this type of approach is the difficulty in interpreting empirical results. It is difficult to interpret whether a positive relationship between concentration and profit/output prices is the evidence of market power, or competitive superiority, or spurious correlation (Demsetz, 1973).

Appelbaum (1982) and Bresnahan (1989) proposed an alternative approach to measure market power, known as the new empirical industrial organization (NEIO). The NEIO methodology posits that market power effects can be estimated via "conduct parameters" estimated from a set of behavioral equations describing firm's production and pricing decisions (Bresnahan, 1989). Recent studies using the NEIO methodology include Schroeter (1988), Azzam and Schroeter (1995), Koontz and Garcia (1997), Paul (2001), and Lopez, Azzam and Espana (2002). Most studies using the NEIO framework to study competition in the U. S. beef processing industry find some level of market power in the cattle procurement market and/or retail beef market (Sexton, 2000; Ward, 2002). However, these studies neglete retailers' potential to exercise market power and therefore could have found biased estimates of market power.

More recently, Azzam (1997) noted that previous studies tend to focus on estimating market power effects while missing potential cost saving effects that might result from the increased concentration. He extended Appelbaum's model by explicitly

separating market power effects from efficiency effects. Azzam found that processors' cost saving effects more than doubled potential oligopsony power effects. However, like previous studies, Azzam's study also focused solely on processors' market power, again neglecting retailers' potential to exercise market power.

Lopez, Azzam, and Espana (2002) developed the oligopoly model analogous to Azzam's (1997) oligopsony model to estimate market power and efficiency effects. Their study with panel data from 32 U.S. manufacturing industries found that oligopoly power effects exceeded cost efficiency effects in nearly every industry, including the beefpacking industry. Again, retailers' potential to exercise market power was not considered.

All previously mentioned studies have certainly contributed toward a better understating of imperfect competition in the U.S. food processing industry. However, these studies have not considered retailers' potential market power separately from processors' potential market power, and therefore, their findings might be misleading.

Our study expands the work of Azzam (1997) and Lopez, Azzam, and Espana (2002), but differs from most previous studies in three important areas. First, our model considers retailers' market power separately from processors' market power. Second, our approach nests the oligopsony-only model (e.g. Azzam, 1997), and the oligopoly-only model (e.g. Lopez, Azzam, and Espana, 2002), which is therefore more general than most previous studies. Third, we use retail concentration data that has not been used in previous studies. Retail level concentration data enables estimation of retailers' potential market power.

A Model of Imperfect Competition in the Beef Packing Industry

Following Blair et al. (1989) and Sexton and Zhang (2001), consider a food industry in which the supply of farm inputs by a perfectly competitive farm sector can be represented by the following inverse supply function:

$$P^{f} = S(Y^{f} \mid \boldsymbol{\gamma}),$$

where Y^{f} is the total supply of farm input, P^{f} is the price per-unit of the farm input, and γ is a vector of supply shifters. Farm input producers sell their product to a concentrated processing sector. Processors, assumed to be symmetric, transform farm inputs into processed product using Leontief technology with a converting factor of one. This, implies that the total supply of farm input (Y^{f}) is equal to the total supply of processed product (Y^{p}) , and the total supply of retail product (Y^{p}) .¹ Further, it is assumed that the cost function for the representative processor, $C(y^{p}, \mathbf{v})$, can be represented by the Generalized Leontief form (Olsonand Shieh, 1989; Baffesard and Vasavada, 1989; Lopez, Azzam, and Espana, 2002) as:

(1.2)
$$C(y^{p}, \mathbf{v}) = y^{p} \sum_{i} \sum_{j} \alpha_{ij} (v_{i}v_{j})^{1/2} + y^{p} t \sum_{i} \lambda_{i} v_{i} + (y^{p})^{2} \sum_{j} \beta_{j} v_{j},$$

where y^p is the output for the representative processor (and $ny^p = Y^p$ is the total supply of processed output by *n* processors in the industry), **v** is a price vector of non-farm inputs such as labor and capital, *t* is a time trend, and α_{ij} , λ_i , and β_j are parameters to be estimated. Processors sell processed product to an imperfectly competitive retail sector facing an inverse demand function represented as:

$$(1.3) P^r = D(Y^r \mid \lambda),$$

where Y^r is the retail supply of processed product, P^r is its per-unit price, and λ is a vector of demand shifters.

A schematic representation of an industry with imperfectly competitive processing and retailing sectors is presented in figure 1. While there is various possibilities of retailer-processor vertical interactions, we consider only three cases for the purpose of simplification. In the first case, processors and retailers are assumed to be integrated in a single "processing/retailing" sector that is allowed to have oligopoly and oligopsony market power. In the second case, retailers are allowed to have both oligopoly and oligopsony power, and processors are allowed to have oligopsony power only. That is, the relationship between retailers and processors is characterized by retailers' domination. In the third case, retailers are allowed to have oligopoly power only, and processors are allowed to possess both oligopsony and oligopoly power. Hence, the relationship between retailers and processors is characterized by processor domination.

Case I. The Integrated Processing/Retailing Sector

We first consider the case where retailers and processors are integrated in a single sector, the "processing/retailing" sector, which competes imperfectly in procuring farm inputs from a perfectly competitive farm sector and in selling processed product to consumers. This bilateral oligopoly model is similar to the models considered in previous studies (e.g. Schroeter, 1988), and provides a benchmark for the three-stage models considered in cases II and III.

The profit maximization problem for a representative "processor/retailer" is:

(1.4)
$$\max_{y^{rp}} \pi^{rp} = [P^{rp}(Y^{rp}) - P^{f}(Y^{f})]y^{rp} - C(y^{rp}, \mathbf{v}),$$

where y^{rp} , P^{rp} , and P^{f} are retail output, retail output price, and farm input price, respectively, and $C(\cdot)$ is the cost function for an integrated "processor/retailer" firm. The total supply of processed beef is represented by $Y^{rp} = \sum_{i=1}^{N} y_{i}^{rp}$. The first order condition for this maximization problem is:

$$\frac{\partial \pi^{rp}}{\partial y^{rp}} = P^{rp} + \left(\frac{dP^{rp}(Y^{rp})}{dY^{rp}}\frac{\partial Y^{rp}}{\partial y^{rp}} - \frac{dP^{f}(Y^{f})}{dY^{f}}\frac{\partial Y^{f}}{\partial y^{rp}}\right)y^{rp} - P^{f} - \frac{\partial C(y^{rp},\mathbf{v})}{\partial y^{rp}} = 0.$$

Rearranging the first order condition yields:

(1.5)
$$P^{rp} = P^{f} - \frac{(1+\phi_{1i})s_{i}^{rp}}{\varepsilon_{d}^{rp}} + \frac{(1+\theta_{1i})s_{i}^{rp}}{\varepsilon_{s}^{f}} + c(y^{rp}, \mathbf{v}),$$

where $c(y^{rp}, \mathbf{v}) = \partial C(y^{rp}, \mathbf{v})/\partial y^{rp}$ is the marginal cost for the representative processor/retailer, $s_i^{rp} = 1/N$ is firm *i*'s market share, $\phi_{1i} = d\sum_{j\neq i}^n y_j^{rp} / dy_i^{rp}$ is the *i*th integrated processor/retailer's conjecture about rivals' responses to a change in final product sales, $\theta_{1i} = d\sum_{j\neq i}^n y_j^f / dy_i^{rp}$ is the *i*th integrated processor/retailer's conjecture about rivals' responses to a change in cattle purchases, and $\varepsilon_d^{rp} = (\partial Y^{rp} / \partial P^{rp})(1/Y^{rp})$ and $\varepsilon_s^f = (dY^f / dP^f)(1/Y^f)$ are semi-elasticities of retail demand and farm supply, respectively.² Equations (1.1), (1.2), (1.3) and (1.5) characterize the market equilibrium for the integrated processor/retailer competing imperfectly in procuring farm inputs and selling final product. The industry pricing equation is obtained from equation (1.5) after substituting $c(y^{rp}, \mathbf{v})$ by the actual expression for the marginal cost, given by the derivative of equation (1.2) with respect to y^{rp} , multiplying equation (1.5) by each firm's market share and summing across all processor/retailers' in the industry as:

(1.6)
$$\sum_{i}^{n} s_{i}^{rp} p^{rp} = \sum_{i}^{n} s_{i}^{rp} p^{f} - \sum_{i}^{n} \left(\frac{(1+\phi_{1i})s_{i}^{rp}s_{i}^{rp}}{\varepsilon_{d}^{rp}} \right) + \sum_{i}^{n} \left(\frac{(1+\theta_{1i})s_{i}^{rp}s_{i}^{rp}}{\varepsilon_{s}^{f}} \right) + \sum_{i}^{n} s_{i}^{rp} \left(\sum_{i} \sum_{j} \alpha_{ij} (v_{i}v_{j})^{1/2} + t \sum_{i} \lambda_{i}v_{i} + 2y_{i}^{rp} \sum_{j} \beta_{j}v_{j} \right)$$

Re-arranging equation (1.6) yields the industry pricing equation:

(1.7)
$$P^{rp} = P^{f} - \frac{H^{rp}L_{\Phi_{1}}}{\varepsilon_{d}^{rp}} + \frac{H^{rp}L_{\Theta_{1}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{i}v_{j})^{1/2} + t\sum_{i}\lambda_{i}v_{i} + 2H^{rp}Y^{rp}\sum_{j}\beta_{j}v_{j},$$

where $L_{\Phi_1} = 1 + \Phi_1$ is the weighed conjectural variation in the retail output market with $\Phi_1 = \sum_i (y_i^{rp})^2 \phi_{1i} / \sum_i (y_i^{rp})^2$, $L_{\Theta_1} = 1 + \Theta_1$ is the weighted conjectural variation in the farm-input market, with $\Theta_1 = \sum_i (y_i^f)^2 \theta_{1i} / \sum_i (y_i^{rp})^2$, and $H^p = (s_i^{rp})^2 = \sum_i (y_i^{rp} / Y^{rp})^2$ is the Herfindahl index in the integrated processing/retailing sector.

If the integrated processing/retailing sector compete perfectly in selling retail output (i.e. $L_{\Phi_1} = 0$), then equation (1.7) is equal to equation (5) in Azzam (1997). If the integrated processing/retailing sector competes perfectly in procuring farm inputs (i.e. $L_{\Theta_1} = 0$), then equation (1.7) is equal to equation (5) in Lopez, Azzam, and Espana (2002). If the integrated processing/retailing sector industry is characterized by the Cournot-type competition in selling final product (procuring farm input), then $L_{\Phi_1} = 1$ $(L_{\Theta_2} = 1)$. Market power effects from an increase in concentration in the processing industry can be separated from cost efficiency effects by differentiating equation (1.7) with respect to the Herfindahl index in the processing industry (H^{rp}) as:

(1.8)
$$\frac{\partial P^{rp}}{\partial H^{rp}} = -\frac{L_{\Phi_1}}{\varepsilon_d^{rp}} + \frac{L_{\Theta_1}}{\varepsilon_s^f} + 2Y^{rp}\sum_j \beta_j v_j.$$

The first two terms in the right-hand side of equation (1.8) capture market power effects in the integrated processing/retailing sector, and the third term captures cost savings for the integrated processing/retailing sector (Azzam, 1997; Lopez et al., 2002).

Case II. Retailer Dominance in the Retailer-Processor Interaction

We now consider the case where retailers have oligopoly power in selling output to consumers and oligopsony power in procuring processed beef from processors. Processors are allowed to have oligopsony power in procuring farm inputs but are price takers when interacting with retailers. The profit maximization problem for a representative processor is:

(1.9)
$$\max_{y^p} \pi^p = P^p y^p - [P^f(Y^f)] y^p - C(y^p, \mathbf{v}),$$

where π^{p} is the profit for the representative processor, and P^{p} and $C(\cdot)$ represent processor's output price and cost function, respectively. Notice that equation (1.9) represents the profit maximization problem for a representative processor only while equation (1.4) is the profit maximization problem for an integrated retailer/processor firm. The first order condition for the maximization problem represented by equation (1.9) is:

$$\frac{d\pi^{p}}{dy^{p}} = P^{p} - (P^{f} + c(y^{p}, \mathbf{v})) - \frac{dP^{f}(Y^{f})}{dY^{f}} \frac{\partial Y^{f}}{\partial y^{p}} y^{p} = 0,$$

which can be re-arranged as:

(1.10)
$$P^{p} = P^{f} + \frac{(1+\theta_{2j})s_{j}^{p}}{\varepsilon_{s}^{f}} + c(y^{p}, \mathbf{v}),$$

where $\theta_{2j} = d \sum_{i \neq j}^{n} y_i^f / dy_j^p$ is the processor *j*'s conjecture about rivals' responses to changes in purchase of farm inputs, and $c(y^p, \mathbf{v}) = \partial C(y^p, \mathbf{v}) / \partial y^p$ is the marginal cost for the representative processor.

Given that retailers are allowed to have oligopsony power in procuring processed beef from beefpackers, retailers maximize profits given a processors' profit-maximization rule. Thus, the profit maximization problem for a representative retailer can be represented as:

(1.11)
$$\max_{y^{r}} \pi^{r} = P^{r}(Y)y^{r} - (P^{p} + m)y^{r}$$

s.t. $P^p = S(Y^p \mid \theta_2, c),$

where y^r and *m* represent finished product sales and per unit constant marketing cost, respectively, and $P^p = S(Y^p | \theta_2, c)$, is the inverse of processors' derived supply, given processors' oligopsony power, obtained by substituting P^f in equation (1.10) by farm supply equation (1.1)

The first order condition for maximizing equation (1.11) is:

$$\frac{\partial \pi^r}{\partial y^r} = P^r + \left(\frac{dP^r(Y^r)}{dY^r}\frac{\partial Y^r}{\partial y^r} - \frac{dP^p(Y^p)}{dY^p}\frac{\partial Y^p}{\partial y^r}\right)y^r - P^p - m = 0.$$

Re-arranging the first order condition yields:

(1.12)
$$P^{r} = P^{p} - \frac{(1+\phi_{2j})s_{j}^{r}}{\varepsilon_{d}^{r}} + \frac{(1+\varpi_{2j})s_{j}^{r}}{\varepsilon_{s}^{p}} + m,$$

where $\varpi_{2j} = d \sum_{i\neq j}^{n} y_i^p / dy_j^r$ is the *j*th retailer's conjecture about rivals' responses to the change in purchases of processed product, $\phi_{2j} = d \sum_{i\neq j}^{n} y_i^r / dy_j^r$ is retailer *j*'s conjecture about rivals' responses to the change in retail sales, $s_j^r = y_j^r / Y^r = 1/N$ represents the *j*th retailers' market share, $\varepsilon_d^r = (\partial Y^r / \partial P^r)(1/Y^r)$ and $\varepsilon_s^p = (\partial Y^p / \partial P^p)(1/Y^p)$ are a semi-elasticities of retail demand and of processors' derived supply given processor oligopsony power, respectively. Equations (1.1), (1.2), and (1.3), (1.10), and (1.12) characterize the market equilibrium for the case of retailer dominance in the retailer-processor interaction.

Replacing $c(\cdot)$ in equation (1.10) with the actual expression of marginal cost, and multiplying equations (1.10) and (1.12) by each firm's market share, and summing across *n* symmetric processors and retailers in the industry, yields the pricing equations for processors and retailers, respectively:

(1.13)
$$P^{p} = P^{f} + \frac{H^{p}L_{\Theta_{2}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{i}v_{j})^{1/2} + t\sum_{i}\lambda_{i}v_{i} + 2H^{p}Y\sum_{j}\beta_{j}v_{j},$$

and,

(1.14)
$$P^{r} = P^{p} - \frac{H^{r}L_{\Phi_{2}}}{\varepsilon_{d}^{r}} + \frac{H^{r}L_{\Psi_{2}}}{\varepsilon_{s}^{p}} + m,$$

where $L_{\Theta_2} = 1 + \Theta_2$ is the weighted conjectural variation in the processing sector with $\Theta_2 = \sum_j (y_j^p)^2 \theta_{2j} / \sum_j (y_j^p)^2$, $L_{\Psi_2} = 1 + \Psi_2$ is the weighted conjectural variation

representing the degree of competition among retailers in procuring processed product,

with $\Psi_2 = \sum_j (y_j^p)^2 \varpi_{2j} / \sum_j (y_j^r)^2$, $L_{\Phi_2} = 1 + \Phi_2$ is a weighted conjectural variation in the retail output market, with $\Phi_2 = \sum_j (y_j^r)^2 \phi_{2j} / \sum_j (y_j^r)^2$; $H^p = \sum_i (y_i^p / Y^p)^2$ is the Herfindahl index for the processing sector, and $H^r = \sum_j (y_j^r / Y^r)^2$ is the Herfindahl index for the retail sector.

Then, market power effects from an increase in concentration in the processing industry can be separated from cost efficiency effects by substituting equation (1.14) into (1.13), and differentiating the resulting equation with respect to the Herfindahl index in the processing sector, as:

(1.15)
$$\frac{\partial P^r}{\partial H^p} = \frac{L_{\Theta_2}}{\varepsilon_s^f} + 2Y^p \sum_j \beta_j v_j.$$

Like in equation (1.8), the first term in the right-hand side of equation (1.15) captures market power effects and the second term captures efficiency effects.

Case III. Processor Dominance in the Retailer-Processor Interaction

We now consider the case where processors are allowed to have oligopsony power in procuring farm inputs, and oligopoly power in selling processed product to retailers. Retailers are allowed to have oligopoly power in selling the final product to consumers, but are assumed to be price takers in their interaction with processors.

The profit maximization problem for a representative retailer is:

$$\max_{y^{r}} \pi^{r} = P^{r}(Y)y^{r} - (P^{p} + m)y^{r},$$

and the first order condition for this problem is:

$$\frac{d\pi^r}{dy^r} = P^r + \frac{dP^r(Y^r)}{dY^r} \frac{\partial Y^r}{\partial y^r} y^r - [P^p + m] = 0.$$

Rearranging the first order condition yields:

(1.16)
$$P^{r} = P^{p} - \frac{(1+\phi_{3j})s_{j}^{r}}{\varepsilon_{d}^{r}} + m.$$

where $\phi_{3j} = d \sum_{i \neq j}^{n} y_i^r / dy_j^r$ is retailer *j*'s conjecture about rivals' responses to the change in retail sales.

Given that processors are allowed to have oligopoly market power in selling processed beef to retailers, they maximize profits taking retailers' profit maximization rule as given. Thus, the profit maximization problem of a representative processor becomes:

$$\max_{y^{p}} \pi^{p} = P^{p} y^{p} - [P^{f}(Y^{f}) + c] y^{p}$$

s.t. $P^{p} = D(Y^{p} | \phi_{3}, m),$

where $P^{p} = D(Y^{p} | \phi_{3}, m)$ is retailers' inverse derived demand, given retailers oligopoly power, obtained by substituting P^{r} in equation (1.16) by retail demand represented by equation (1.3).

The first order condition for the profit maximization problem of the representative processor is:

$$\frac{\partial \pi^{p}}{\partial y^{p}} = P^{p} + \left[\frac{dP(Y^{p})}{dY^{p}}\frac{\partial Y^{p}}{\partial y^{p}} - \frac{dP^{f}(Y^{f})}{dY^{f}}\frac{\partial Y^{f}}{\partial y^{p}}\right]y^{p} - P^{f} - c = 0,$$

which can be re-arranged as:

(1.17)
$$P^{p} = P^{f} - \frac{(1+\overline{\omega}_{3i})s_{i}}{\varepsilon_{d}^{p}} + \frac{(1+\theta_{3i})s_{i}}{\varepsilon_{s}^{f}} + c(y^{p}, \mathbf{v}),$$

where $\varpi_{3i} = d\sum_{i\neq j}^{n} y_{j}^{p} / dy_{i}^{p}$ is processors *i*'s conjecture about rivals' responses to changes in sales of processed product, $\theta_{3i} = d\sum_{j\neq i}^{n} y_{j}^{f} / dy_{i}^{p}$ is processor *i*'s conjecture about rivals' responses to changes in purchase of farm inputs, and $\varepsilon_{d}^{p} = (\partial Y^{p} / \partial P^{p})(1/Y^{p})$ is the semi-elasticity of retailers' derived demand for processing services, given retailers oligopoly power. The equilibrium condition for the case of processor dominance is described by equations (1.16), (1.17) together with equations (1.1), (1.2), and (1.3).

Multiplying equations (1.16) and (1.17) by each processor's market share, and summing across n firms in the industry yields the pricing equations for retailers and processors, respectively:

(1.18)
$$P^{p} = P^{f} - \frac{H^{p}L_{\Psi_{3}}}{\varepsilon_{d}^{p}} + \frac{H^{p}L_{\Theta_{3}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{i}v_{j})^{1/2} + t\sum_{i}\lambda_{i}v_{i} + 2H^{p}Y\sum_{j}\beta_{j}v_{j},$$

and,

(1.19)
$$P^r = P^p - \frac{H^r L_{\Phi_3}}{\varepsilon_d^r} + m,$$

where $L_{\Psi_3} = 1 + \Psi_3$ is the weighted conjectural variation representing processors' competition in selling processed product, with $\Psi_3 = \sum_i (y_i^p)^2 \varpi_{3i} / \sum_i (y_i^p)^2$; $L_{\Theta_3} = 1 + \Theta_3$ is the weighed conjectural variation representing the degree of competition among processors in procuring cattle with $\Theta_3 = \sum_i (y_i^p)^2 \theta_{3i} / \sum_i (y_i^p)^2$.

Market power effects from an increase in concentration in the processing sector can be separated from cost efficiency effects by substituting equation (1.18) into equation (1.19), and then differentiating the resulting equation with respect to the Herfindahl index in the processing industry as:

(1.20)
$$\frac{\partial P^r}{\partial H^p} = -\frac{L_{\Psi_3}}{\varepsilon_d^p} + \frac{L_{\Theta_3}}{\varepsilon_s^f} + 2Y^p \sum_j \beta_j v_j.$$

The first two terms in the right hand side capture market power effects and the third term captures efficiency effects.

In all three cases of imperfect competition outlined previously, processors technology remains unchanged. It is assumed that processors use a farm input (cattle) and non-farm inputs such as labor, capital, and packing materials in producing retail output. Non-farm inputs are purchased in perfectly competitive markets. Industry nonfarm input demand schedules are obtained by applying Shephard's lemma on the industry-level processing cost function represented by equation (1.2), as:

$$\frac{\partial C(\boldsymbol{y}^{p}, \mathbf{v})}{\partial \boldsymbol{v}_{j}} = \frac{1}{2} \boldsymbol{Y}^{p} \sum_{i} \sum_{j} \alpha_{ij} (\boldsymbol{v}_{i} / \boldsymbol{v}_{j})^{1/2} + \boldsymbol{Y}^{p} t \lambda_{i} + \beta_{j} H^{p} (\boldsymbol{Y}^{p})^{2},$$

which can be re-arranged as:

(1.21)
$$\frac{X_j}{Y} = \frac{1}{2} \sum_{i} \sum_{j} \alpha_{ij} (v_i / v_j)^{1/2} + t\lambda_i + H^p Y \beta_j,$$

where X_j is the industry-level derived demand for the *j*th non-farm input purchased in a perfectly competitive market. Notice that the cost function represented by equation (1.2) satisfies economic restrictions since it is (*i*) nondecreasing in output quantity, (*ii*) homogeneous of degree one in input prices, and (*iii*) nondecreasing in and input prices. Symmetry is achieved by imposing $\alpha_{ij} = \alpha_{ji}$ during the empirical estimation.

Data and Empirical Procedures

This study uses a quarterly data series for the U.S. beef industry ranging from 1970 to 1999. The prices of labor and packing materials for the U.S. beef packing industry (SIC 2011) are obtained from the National Bureau of Economic Research (NBER) database (Bartelsman et al., 2000). The price of materials is represented by NBER's index for materials, and wage per work-hour is computed by dividing NBER's total payroll by the total number of production work-hours in the industry. The rental price of capital, and the productivity of capital, labor and processing materials are 2-digit SIC data for Food & Kindred Products provided by the Bureau of Labor Statistics. The total supply of commercial beef and the retail price of beef, inventory of beef cows, wholesale value and net farm value of cattle are provided by the Economic Research Service, United States Department of Agriculture.³ The consumer price index and the producer price index for farm output are also from the Bureau of Labor Statistics (BLS).

The Herfindahl index for the U.S. beef processing industry is the steer and heifer slaughter concentration index compiled from several annual reports from the Packers and Stockyards Statistical Report (1996 - 2004). Retail Herfindahl index for years 1973-1980 and 1999-2001 are estimated using sales data of the 50 largest grocery stores in the United States. These retail sales data are obtained from several issues of the Progressive Grocer magazine. The Herfindahl index data for the remaining years, 1981-1998, are estimated in two steps. First, estimated Herfindahl indices for years 1973-1980, and 1999-2001 are regressed against a four-firm grocery store concentration computed using data from various issues of Progressive Grocer, and from the United States Department of Agriculture (Harris et al., 2002). Next, missing values of the Herfindahl index are

predicted using the regression equation estimated in the first step. Annual data are used for population, cattle inventory, Herfindahl index, personal disposable income, beef demand, and price and quantity of labor, capital and processing materials (including energy).⁴ Descriptive statistics for the variables used in the empirical estimation are reported in table I-1.

Farm-input supply and retail-output demand functions need to be specified before proceeding with estimation of the three analytical models of imperfect competition outlined previously. Farm-input supply and retail-output demand functions are represented as:

(1.22)
$$\ln Y = \alpha_0 + \alpha_1 (p^{corn} / PPI) + \alpha_2 (p^{diesel} / PPI) + \alpha_3 (p^{calves} / PPI) + \varepsilon_s^f (p^f / PPI),$$

and,

(1.23)
$$\ln Y = \delta_0 + \delta_1 t + \delta_2 (p^{pork} / CPI) + \delta_3 (I / CPI) + \delta_4 (p^{turkey} / CPI) + \varepsilon_d^r (p^r / CPI),$$

where *CPI* is the consumer price index, and *PPI* is the producer price index for farm products.

Demand and supply functions are specified in log-linear form to conform to analytical derivation of pricing rules, which considered semi-elasticities of demand and supply. Also, the log-linear specification allows for nonlinearities between prices and quantities. The system of equations used in the estimation of cases I, II, and III are shown in table I-2, I-3, and I-4.⁵ Each system of equations was estimated jointly via generalized methods of moments (GMM) using the MODEL Procedure in SAS 9.1 (The SAS Institute, 2002-03). The GMM was used because the Breusch-Godfrey test for

autocorrelation (Breusch, 1978; Godfrey, 1978) rejected the null hypothesis of no first firt order autocorrelation on the residuals of each equation.

Results

Parameter estimates of the three models of imperfect competition are reported in tables I-5, I-6, and I-7. All parameter estimates are significant at the 5% level. Own price elasticities for retail demand and cattle supply have the expected signs and magnitude, but the elasticity of processors' derived supply given processors' oligopsony power (case II) and the elasticity of retailers' derived demand are large (case III). Therefore retailers may not exercise market power on processors because processor's supply of marketing services, given processor's oligopsony power, is very responsive to changes in demand prices. Likewise, processor's may not exercise marker power on retailers because retailer's demand for processor's marketing services, given retailer's oligopoly power, is very responsive to changes in supply prices. Notice that with a large supply elasticity of processors' supply, the first term of the right-hand side of equation (1.20) becomes zero and equation (1.20) becomes similar to equation (1.15). Consequently, processors are unlikely to exercise oligopoly market power on retailers.

While results suggest that processors are unlikely to exercise market power on and retailers, and vice versa, retailers were expected to have some buying power on processors because processors need to deal with perishability while retailers need not. Intuitively, perishability could narrow the time available for processors to market processed beef, leaving them vulnerable to retailers' attempt to decrease their procurement prices. Processors' payment of slotting fees to retailers' would also seem to

suggest that retailers can exercise some market power on processors. However, the elasticity of processors' derived supply and retailer's derived demand suggest that retailers and processors bargain in deciding how much product to sell and in allocating profits among them. Negotiation is one of the expected outcomes when monopoly "meets" monopsony.

Tables I-5, I-6, and I-7 also show estimates of industry-weighted conjectural variations (L_{Θ_4} and L_{Φ_4} , i = 1, 2, 3) and corresponding Likelihood Ratio 95% confidence intervals.⁶ Results show that the conjectural variation estimate for the integrated "processing/retailing" sector ($L_{\Phi_1} = 1.9E-5$) is three times bigger than the estimate of processors conjectural in cases II and III ($L_{\Theta_2} = L_{\Theta_3} = 5.6E-6$), but smaller than the retailers' conjectural variation in cases II and III ($L_{\Phi_2} = L_{\Phi_3} = 0.0015$). Thus, previous studies not allowing retailers' market power separately from processors' market power may have overestimated processors' market power and underestimated retailers' potential market power. Given that retailers and processors are unlikely to exert market power on each other, most oligopoly power in case I is likely from retailers, and most oligopsony power is likely from processors in the U. S. beef industry are unlikely to set prices when dealing with retailers.

Table I-8 shows direct estimates of market power effects, and cost efficiency effects, and corresponding Wald 95% confidence intervals. The estimates of market power effects and cost efficiency effects from an increase in industry concentration were obtained using equations (1.8), (1.15) and (1.20). Standard errors used to compute Wald confidence intervals are obtained with the delta method (Greene, 2000). Notice that

market power effects depend on both conjectural variation and demand/supply estimates. So, market power effects could still be insignificant even with statistically significant conjectural variation estimates.

Results in table I-8 show that processors' oligopsony power effects $(L_{\Theta_i} / \varepsilon_s^f)$ are significant at the 5% level in all three cases of imperfect competition considered. But processors' market power effects are bigger when retailers and processors assumed integrated in a single "processing/retailing" sector (case I) than when processors' market power is considered separately from retailers' market power (cases II and III). Again, results show that estimates of market power and/or its effects are sensitive to researchers' *ex ante* assumptions about market structure, and retailers' potential to exercise market power should not be ignored. Most previous studies might have overestimated processor's market power and/or its effects because retailers' potential market power was not considered separately from processors' potential market power.

Total price effects from an increased concentration in the beefpacking industry are obtained by summing market power effects and efficiency effects (equations 1.8, 1.15, and 1.20). Efficiency effects are significant at the 5% level and dominate market power effects in all three cases of imperfect competition considered. However, efficiency effects are slightly bigger when processors and retailers are considered integrated in a single "processing/retailing" sector than when processors' market power is separated from retailers' market power. The finding that efficiency effects dominate market power effects is consistent with the findings in Azzam (1997) and Paul (2001). However, it clearly contradicts the finding in Lopez, Azzam, and Espana (2002) that market power

effects from an increase in concentration in the U.S. beef packing dominate potential cost savings.

Estimates of cost elasticity, calculated as a ratio of marginal processing costs to average processing costs, are nearly one (0.99). These estimates suggest that processors are operating near constant returns to scale and that potential efficiency gains are small, if any. Thus, further increases in concentration in the beef-processing sector might not yield significant cost economies. Lopez, Azzam, and Espana (2002) and Paul (2001) reported returns to scale of about 0.95.

Conclusions

Many recent studies have estimated potential market power effects from increased concentration in the U. S. beef processing industry. However, these studies have paid little attention to retailer's potential to exercise market power. In reality, retailers tend to be bigger than processors. Retailers also have the ability to charge several fees to processors such as slotting fees.

This paper separated retailers' potential market power from processors' potential market power and estimated the tradeoff between market power and cost efficiency from an increase in concentration in the U.S. beef processing industry. The model is based on pricing rules from the first order conditions of firm's profit maximization, and nests most models considered in previous studies.

Results suggest that processors have limited ability to exercise oligopsony market power in procuring cattle and are unlikely to exercise market power on retailers. The relationship between retailers and processors is likely characterized by mutual bargaining

with no dominance of either retailers or processors. Processors market power effects were bigger when processors and retailers were assumed integrated in a single sector than when retailers' market power was considered separately from processors' market power. Thus, previous studies not considering retailers' potential market power separately from processors' market power might have overestimated processors market power and/or its effects. Results show that efficiency effects from the increased concentration in the U. S. beef packing industry are only slightly bigger than market power effects, especially when retailers and processors are considered separately (cases II and III). The sensitivity of market power estimates to *ex ante* choices of market structure calls for the use of more flexible models, such as those in cases II and III, considering retailers' market power separately from processor's market power. Cost elasticity estimates indicate that beef processors operate near constant returns to scale (0.99), suggesting little economies of scale, if any.

This study's results have important policy implications. They suggest that consolidations in the beef packing industry have not led to market power exploitation by packers. Rather, the beef processing industry seems very competitive. But given that potential cost savings are small, further increase in concentration might lead market power effects greater than cost savings effects. Results from recent studies including our study seem to suggest that legislation and monitoring systems have been working well in preventing anticompetitive behavior by beef packers. But this might not be true for retailers since retailers' potential market power seem more important than processors' potential market power. More research is needed to determine whether changes in

concentration at the retail level have reduced competition in both upstream and downstream markets in the U. S. food industry.

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Notes

- Most studies of imperfect competition in the U.S food industry use the Leontief type technology. For example Azzam (1997), and Paul (2001) have used a similar assumption for in studying competition in the U.S. beef packing industry.
- A semi-elasticity is a percentage change in quantity due to a level change in price. Alternatively, a semi-elasticity can be interpreted as an elasticity evaluated at price one.
- 3. The farm value of cattle is divided by a productivity index to reflect the fact that more beef has been produced per cow over time. The productivity index was computed as the ratio between total beef supply and the number of cows.
- 4. Due to the lack of data, the empirical section assumes that retailer's marketing cost is zero.
- 5. Notice that we have imposed $L_{\Phi_1} = L_{\Theta_1}$, and $L_{\Psi_2} = L_{\Phi_2}$, and $L_{\Psi_3} = L_{\Theta_3}$ during empirical estimation. This restriction is consistent with the assumption of fixed proportions technology and helps in achieving identification of the system of equations. Schroeter (1988) used a similar restriction.
- 6. Likelihood ratio confidence intervals are derived from the χ² distribution of the generalized likelihood ratio test, and are computed iteratively using the MODEL procedure in SAS 9.1. The approximate 1-α confidence interval for a parameter κ can be represented as κ: 2[l(κ̂) l(κ)] ≤ q_{1,1-α} = 2l*, where q_{1,1-α} is the (1-α) quantile

of the χ^2 distribution with one degree of freedom, and $l(\kappa)$ is the log likelihood as a function of one parameter. The endpoints of a confidence interval are the zeros of the function $l(\kappa)$ - l^* (SAS/ETS, SAS 9.1).


Figure I-1. Schematic representation of a three-sector model of imperfect competition within and between retailing and processing sectors.

Variable	Symbol	Mean	Standard deviation	Minimum	Maximum
Commercial beef production (billion lbs.)	Y	23.42	1.42	21.09	26.39
Retail price of beef (\$/lb)	P^r	2.23	0.62	0.99	3.00
Wholesale value of beef (\$/lb)	P^p	1.48	0.33	0.73	1.96
Farm value of beef (\$/lb)	P^f	1.27	0.30	0.61	1.74
Retail price of pork (\$/lb)	P^{pork}	1.72	0.51	0.68	2.48
Price of turkey (\$/cwt)	P ^{turkey}	0.80	0.14	0.48	0.97
Per capita income (thousand \$)	Ι	12.71	6.39	3.59	23.97
Consumer price index (84-86 = 100)	CPI	103.03	39.20	38.80	165.20
Producer price index $(82 = 100)$	PPI	93.76	19.58	44.30	127.90
Price of No2 diesel (\$/gallon)	P^{diesel}	0.60	0.21	0.13	1.09
Price of corn (\$/bus)	P^{corn}	2.31	0.60	1.00	4.10
Price of calves (\$/cwt)	P^{calves}	67.35	22.09	24.40	107.33
Price deflator for materials (1987=1)	v_M	0.87	0.21	0.42	1.16
Price of labor (\$/hour)	v_L	7.75	1.71	4.04	9.94
Rental price of capital		60.60	25 20	0.15	1 21
(2000 = 1)	V_K	09.00	55.59	0.15	1.51
Productivity of materials (1996=100)	Y/X_M	104.87	3.45	98.70	111.00
Productivity of capital (1996=100)	Y/X_K	101.48	3.15	97.00	110.10
Productivity of workers (1996=100)	Y/X_L	83.17	15.06	56.60	106.30
Herfindahl index for steer and heifer slaughter	H^{p}	1135.80	693.38	163.00	2096.00
Herfindahl index for grocery stores	H^{r}	119.74	44.28	80.60	284.60
Population (millions)		239.13	21.77	205.05	279.30
Total stock of beef cows (million/head)		36.74	3.56	32.45	45.71

Table I-1.Means, Standard Errors, Maximum and Minimum Values of
Variables Used in the Empirical Estimation (N=120, 1970.I-1999.IV)

Table I-2.Equations Used in Empirical Estimation of the Models Described in
Case I.

$$P_{t}^{rp} = P_{t}^{f} - \frac{H_{t}^{rp}L_{\Phi_{1}}}{\varepsilon_{d}^{r}} + \frac{H_{t}^{rp}L_{\Phi_{1}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{it}v_{jt})^{1/2} + t\sum_{i}\lambda_{it}v_{it} + 2H_{t}^{rp}Y_{t}\sum_{j}\beta_{j}v_{jt} + \varepsilon_{t}$$

$$\frac{X_{jt}}{Y_{t}} = \alpha_{0j} + \frac{1}{2}\sum_{i}\sum_{j}\alpha_{ij}(v_{it}/v_{jt})^{1/2} + t\lambda_{i} + H_{t}^{rp}Y_{t}\beta_{j} + v_{it}, \quad (j = \text{capital, labor, packing materials})$$

$$\ln Y_{t} = \delta_{0} + \delta_{1}t + \delta_{2}(P_{t}^{pork}/CPI_{t}) + \delta_{3}(I_{t}/CPI_{t}) + \delta_{4}(P_{t}^{turkey}/CPI_{t}) + \varepsilon_{d}^{r}(P_{t}^{r}/CPI_{t}) + \eta_{t}$$

$$\ln Y_{t} = \alpha_{0} + \alpha_{1}t + \alpha_{2}(P_{t}^{corn}/PPI_{t}) + \alpha_{3}(P_{t}^{diesel}/PPI_{t}) + \alpha_{4}(P_{t}^{calves}/PPI_{t}) + \varepsilon_{s}^{f}(P_{t}^{f}/PPI_{t}) + \mu_{t}$$

Table I-3.Equations Used in Empirical Estimation of the Model Described in
Case II.

$$\begin{split} P_{t}^{p} &= P_{t}^{f} + \frac{H_{t}^{p}L_{\Theta_{2}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{ii}v_{ji})^{1/2} + t\sum_{i}\lambda_{it}v_{it} + 2H_{t}^{p}Y_{t}\sum_{j}\beta_{j}v_{jt} + v_{t} \\ P_{t}^{r} &= P_{t}^{p} - \frac{H_{t}^{r}L_{\Phi_{2}}}{\varepsilon_{d}^{r}} + \frac{H_{t}^{r}L_{\Psi_{2}}}{\varepsilon_{s}^{p}} + \varepsilon_{t} \\ \frac{X_{jt}}{Y_{t}} &= \alpha_{0j} + \frac{1}{2}\sum_{i}\sum_{j}\alpha_{ij}(v_{it}/v_{jt})^{1/2} + t\lambda_{i} + H_{t}^{p}Y_{t}\beta_{j} + v_{jt}, \ (j = \text{capital, labor, packing materials}) \\ \ln Y_{t} &= \delta_{0} + \delta_{1}t + \delta_{2}(P_{t}^{pork}/CPI_{t}) + \delta_{3}(I_{t}/CPI_{t}) + \delta_{4}(P_{t}^{turkey}/CPI_{t}) + \varepsilon_{d}^{r}(P_{t}^{r}/CPI_{t}) + \eta_{t} \\ \ln Y_{t} &= \alpha_{0} + \alpha_{1}(P_{t}^{corn}/PPI_{t}) + \alpha_{2}(P_{t}^{diesel}/PPI_{t}) + \alpha_{3}(P_{t}^{calves}/PPI_{t}) \\ &+ \varepsilon_{s}^{f}(P_{t}^{f}/PPI_{t}) + \mu_{t} \end{split}$$

Table I-4.Equations Used in Empirical Estimation of the Model Described in
Case III.

$$P_{t}^{p} = P_{t}^{f} + \frac{H_{t}^{p}L_{\Theta_{2}}}{\varepsilon_{s}^{f}} + \sum_{i}\sum_{j}\alpha_{ij}(v_{it}v_{jt})^{1/2} + t\sum_{i}\lambda_{it}v_{it} + 2H_{t}^{p}Y_{t}\sum_{j}\beta_{j}v_{jt} + v_{t}$$

$$P_{t}^{r} = P_{t}^{p} - \frac{H_{t}^{r}L_{\Phi_{2}}}{\varepsilon_{d}^{r}} + \frac{H_{t}^{r}L_{\Psi_{2}}}{\varepsilon_{s}^{p}} + \varepsilon_{t}$$

$$\frac{X_{jt}}{Y_{t}} = \alpha_{0j} + \frac{1}{2}\sum_{i}\sum_{j}\alpha_{ij}(v_{it}/v_{jt})^{1/2} + t\lambda_{i} + H_{t}^{p}Y_{t}\beta_{j} + v_{jt}, \ (j = \text{capital, labor, packing materials})$$

$$\ln Y_{t} = \delta_{0} + \delta_{1}t + \delta_{2}(P_{t}^{pork}/CPI_{t}) + \delta_{3}(I_{t}/CPI_{t}) + \delta_{4}(P_{t}^{turkey}/CPI_{t}) + \varepsilon_{d}^{r}(P_{t}^{r}/CPI_{t}) + \eta_{t}$$

$$\ln Y_{t} = \alpha_{0} + \alpha_{1}(P_{t}^{corn}/PPI_{t}) + \alpha_{2}(P_{t}^{diesel}/PPI_{t}) + \alpha_{3}(P_{t}^{calves}/PPI_{t})$$

$$+ \varepsilon_{s}^{f}(P_{t}^{f}/PPI_{t}) + \mu_{t}$$

	Parameter	Asymptotic	Likelihood Ratio 95% confidence interval		
Symbol	estimate	standard error	Lower	Upper	
L_{Φ_2}	1.9E-05	1.2E-06	1.7E-05	2.1E-05	
${\cal E}_d^r$	-0.2849	0.0151	-0.3086	-0.2607	
${\cal E}_s^f$	0.2184	0.0118	0.1992	0.2378	
$lpha_{LL}$	0.1304	0.0060	0.1207	0.1390	
$lpha_{KK}$	0.0138	0.0011	0.0120	0.0156	
$lpha_{MM}$	0.0124	0.0027	0.0075	0.0171	
$lpha_{K\!L}$	-0.0544	0.0050	-0.0625	-0.0464	
$lpha_{M\!L}$	-0.0069	0.0021	-0.0105	-0.0032	
$lpha_{KM}$	0.0043	0.0004	0.0036	0.0050	
λ_L	-3.2E-04	4.3E-05	-3.8E-04	-2.5E-04	
λ_K	9.0E-05	6.6E-06	8.0E-05	1.0E-04	
λ_M	2.0E-04	7.7E-06	1.9E-04	2.1E-04	
$eta_{\!L}$	5.6E-07	6.3E-08	4.4E-07	6.6E-07	
$eta_{\scriptscriptstyle K}$	-1.5E-07	8.0E-09	-1.6E-07	-1.3E-07	
eta_M	-7.4E-07	2.6E-08	-7.9E-07	-7.0E-07	
δ_0	4.1586	0.1041	4.0068	4.3113	
δ_1	0.0019	0.0005	0.0011	0.0028	
δ_2	0.0274	0.0107	0.0099	0.0446	
δ_3	-0.0434	0.0056	-0.0525	-0.0352	
δ_4	0.1349	0.0384	0.0746	0.1919	
$lpha_0$	3.2402	0.0266	3.1911	3.2600	
α_1	-0.0320	0.0060	-0.0424	-0.0207	
α_2	-0.0792	0.0052	-0.0879	-0.0705	
α_3	-0.4631	0.0212	-0.4988	-0.4275	

Table I-5.Generalized Method of Moments Estimates and Likelihood Ratio
Confidence Intervals for Case I (N=120, 1970.I-1999.IV)

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

	Parameter	Asymptotic standard error	Likelihood Ratio 95% confidence interval		
Symbol	estimate		Lower	Upper	
L_{Φ_2}	0.0015	2.8E-05	0.0015	0.0016	
L_{Θ_2}	5.6E-06	8.6E-07	3.9E-06	7.3E-06	
${\mathcal E}_d^r$	-0.2725	0.0051	-0.2824	-0.2625	
\mathcal{E}_{s}^{f}	0.2096	0.0043	0.1990	0.2202	
\mathcal{E}_{s}^{p}	4.6E+63	3.5E-125	-	-	
$lpha_{LL}$	-0.0084	0.0014	-0.0110	-0.0057	
$lpha_{KK}$	-0.0148	3.6E-04	-0.0155	-0.0141	
$lpha_{MM}$	0.0160	4.0E-04	0.0152	0.0168	
$lpha_{K\!L}$	0.0563	0.0014	0.0536	0.0591	
$lpha_{M\!L}$	-0.0193	4.9E-04	-0.0203	-0.0184	
$lpha_{KM}$	0.0086	1.6E-04	0.0083	0.0089	
λ_L	-5.9E-04	5.4E-06	-6.0E-04	-5.8E-04	
λ_K	3.5E-05	1.5E-06	3.2E-05	3.8E-05	
λ_M	6.8E-05	2.9E-06	6.2E-05	7.4E-05	
$eta_{\scriptscriptstyle L}$	-3.6E-07	2.1E-08	-4.0E-07	-3.1E-07	
β_K	1.6E-08	1.9E-09	1.2E-08	2.0E-08	
eta_M	-6.6E-07	5.8E-09	-6.7E-07	-6.5E-07	
δ_0	4.0570	0.0358	3.9868	4.1272	
$\delta_{ m l}$	0.0014	1.4E-04	0.0012	0.0017	
δ_2	0.0463	0.0045	0.0353	0.0573	
δ_3	-0.0356	0.0014	-0.0390	-0.0321	
δ_4	0.0926	0.0135	0.0660	0.1191	
$lpha_0$	3.2358	0.0134	3.2095	3.2622	
α_1	-0.0312	0.0032	-0.0374	-0.0250	
α_2	-0.0768	0.0022	-0.0811	-0.0725	
α_3	-0.4398	0.0074	-0.4543	-0.4252	

Table I-6.Generalized Method of Moments Estimates and Likelihood Ratio
Confidence Intervals for Case II (N=120, 1970.I-1999.IV)

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

	Parameter	Asymptotic standard error	Likelihood Ratio 95% confidence interval		
Symbol	estimate		Lower	Upper	
L_{Φ_2}	0.0015	3.0E-05	0.0015	0.0016	
L_{Θ_2}	5.6E-06	1.2E-06	5.7E-06	3.3E-06	
${\mathcal E}_d^r$	-0.2710	0.0054	-0.2710	-0.2815	
\mathcal{E}_{s}^{f}	0.2117	0.0035	0.2117	0.2031	
${\cal E}_d^{p}$	-1.0E+40	2.9E-78	-	-	
$lpha_{\scriptscriptstyle LL}$	-0.0086	0.0011	-0.0086	-0.0108	
$lpha_{KK}$	-0.0149	4.1E-04	-0.0149	-0.0157	
$lpha_{MM}$	0.0161	5.1E-04	0.0161	0.0151	
$lpha_{lK}$	0.0566	0.0013	0.0566	0.0540	
$lpha_{lM}$	-0.0193	6.3E-04	-0.0193	-0.0206	
$lpha_{MK}$	0.0086	1.9E-04	0.0086	0.0082	
λ_L	-5.9E-04	7.2E-06	-5.9E-04	-6.0E-04	
λ_K	3.5E-05	2.5E-06	3.5E-05	3.0E-05	
λ_M	6.9E-05	2.8E-06	6.9E-05	6.3E-05	
$eta_{\!L}$	-3.6E-07	1.9E-08	-3.6E-07	-4.0E-07	
β_K	1.6E-08	1.9E-09	1.6E-08	1.2E-08	
β_M	-6.6E-07	7.7E-09	-6.6E-07	-6.7E-07	
δ_0	4.0544	0.0373	4.0544	3.9626	
$\delta_{ m l}$	0.0014	1.2E-04	0.0014	0.0012	
δ_2	0.0454	0.0049	0.0454	0.0358	
δ_3	-0.0356	0.0015	-0.0356	-0.0385	
δ_4	0.0928	0.0104	0.0928	0.0671	
$lpha_0$	3.2380	0.0093	3.2380	3.2151	
α_1	-0.0315	0.0023	-0.0314	-0.0360	
α_2	-0.0763	0.0022	-0.0762	-0.0805	
α_3	-0.4472	0.0081	-0.4472	-0.4630	

Table I-7.Generalized Method of Moments Estimates and Likelihood Ratio
Confidence Intervals for Case III (N=120, 1970.I-1999.IV)

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

Effect of concentration increase	Parameter	Asymptotic	Wald 95% confidence interval			
the processing industry estimate		standard error	Lower	Upper		
Case I: Integrated Retailing/processing sector						
Oligopoly $(L_{\Phi_1} / \varepsilon_d^r)$	6.5E-05	5.0E-06	5.5E-05	7.5E-05		
Oligopsony $(L_{\Phi_1} / \varepsilon_s^f)$	8.5E-05	5.6E-06	7.4E-05	9.6E-05		
Cost saving $(2Y \sum_{j} \beta_{j} v_{j})$	-3.1E-04	1.1E-05	-3.3E-04	-2.9E-04		
Total effect	-1.5E-04	4.6E-06	-1.6E-04	-1.4E-04		
Case II: Retailers dominance in the retailer-processor interaction						
Oligopsony $(L_{\Theta_2} / \mathcal{E}_s^f)$	2.7E-05	4.1E-06	1.9E-05	3.5E-05		
Cost saving $(2Y \sum_{j} \beta_{j} v_{j})$	-1.0E-04	6.4E-06	-1.1E-04	-8.7E-05		
Total effect	-8.0E-05	2.7E-06	-8.5E-05	-7.5E-05		
Case III: Processor dominance in the retailer-processor interaction						
Oligopoly $(L_{\Phi_3} / \varepsilon_d^p)$	5.7E-46	1.2E-46	3.3E-46	8.1E-46		
Oligopsony $(L_{\Theta_3} / \mathcal{E}_s^f)$	2.7E-05	5.6E-06	1.6E-05	3.8E-05		
Cost saving $(2Y \sum_{j} \beta_{j} v_{j})$	-1.0E-04	8.7E-06	-1.2E-04	-8.3E-05		
Total effect	-8.0E-05	3.4E-06	-8.7E-05	-7.3E-05		

Table I-8.Market Power Effects and Efficiency Effects for Three Cases of
Imperfect Competition in the United States Beef Industry

Note: All parameter estimates are significant at the 5% level. Standard errors were computed using the delta method (Greene, 2000).

ESSAY II

INTEGRATING AUCTION THEORY WITH TRADITIONAL MEASURES OF MARKET POWER

Introduction

Potential anti-competitive behavior of beef packers in cattle procurement markets has been heavily researched (Schroeter, 1988; Azzam, 1997; Sexton 2000; Paul 2001; Lopez et al., 2002, Ward, 2002). Cattle producers contend that they receive lower cattle prices because packers act strategically to depress purchase prices below competitive market prices. For past decades, the four firm concentration ratio in the U. S. beef packing industry has increased significantly from 25% in 1976 to about 80% in 1998 (Ward, 2002), which increases concern about possible packer market power in cattle procurement markets.

In general, there have been two types of approaches developed in the literature to measure market power in the cattle procurement market – auction model and new empirical industrial organization (NEIO) model. Most recent empirical studies of competition in cattle markets use the NEIO model to explain market power from industry-level imperfect competition (Schroeter, 1988; Azzam, 1997; Koontz and Garcia, 1997; Sexton, 2000; Paul, 2001; Lopez et al., 2002). These studies using the NEIO model find little market power in cattle procurement markets (Sexton, 2000; Ward,

2002). A few empirical studies have looked at disaggregate measures of concentration such as the number of bidders at auctions. These latter studies of market power are based on concepts from auction theory (Milgrom and Weber, 1982; Laffont and Vuong, 1996, Klemperer, 1999). Auction models are agent-based models that can be used to explain market power due to bid-shading at individual markets such as local cattle auctions (Bailey, Brorsen, and Fawson, 1993), rice auctions (Meyer, 1988), grain auctions (Bourgeon and Le Roux, 1996, 2001; Banerji and Meenakshi, 2004), and timber contract auctions (Baldwin, Marshall, and Richard, 1997). Bailey, Brorsen, and Fawson (1993) found an increase in concentration at local auctions depressed cattle prices, but the effect was small. Crespi and Sexton (2004) found differences between the buying pattern predicted by their bid model and the buying pattern present in the original cattle auction data.

Although the empirical literature has mostly used the NEIO model, auction models seem more closely tied to the way cattle markets work since cattle buyers make a large number of individual purchase decisions rather than setting a single equilibrium price. The emphasis on the NEIO model may be due more to data availability than to its appropriateness for cattle procurement markets where prices are remade in each transaction.

While NEIO models are based on equilibrium prices determined by industry-level demand and supply, auction models involve transaction prices determined by buyers and sellers for given quantities and quality of cattle at a particular place and time. Thus, auction theory is associated with price discovery (i.e. focusing on microstructure), and the NEIO model is associated with price determination (i.e. focusing on macrostructure).

These concepts may be interrelated, but are not the same (Ward and Schroeder, 2001). Also, firm strategic behavior and potential antitrust policy implied by each of these models are different. While both models have been used in the literature, there have been important unanswered questions such as what is the relationship between traditional measures of market power and auction models? Which of these two models estimate market power more accurately? Answers to these questions may require a model considering both auction theory's bid shading and industry-level imperfect competition. To our knowledge, such a model has not been developed in the literature.

The objective of our study is to determine the relationship between auction and traditional new empirical industrial organization (NEIO) models of market power, and examine their relative accuracies. An integrated model considering auction-level and market-level markdowns is used to show the relationship between market power measures from traditional NEIO and auction models. Cattle price markdowns are estimated with each of these two models and compared with the "true" markups from an experimental cattle market. Lastly, aggregate measures of market power are indirectly tested against disaggregate measures of market power.

Market Power in Cattle Procurement Markets

This section reviews the two major models of possible market power: the NEIO model and the auction model. The NEIO model is game-theoretic and posits that firms make decisions as if they played "conjectural variations" games. A typical NEIO model consists of a set of behavioral equations describing firm's production and pricing decisions (Appelbaum, 1982; Bresnahan, 1989). These demand and supply relationships

reflecting the "conjectural variations" game are specified and estimated jointly to yield a set of "conduct parameters," measuring the degree of competitiveness of the market as a whole. These "conduct parameters" often nest a range of competitive outcomes from perfect competition to monopoly or monopsony.

The intuition behind the NEIO model is that market power is inversely related to the number of firms in the (aggregate) industry and depends on the conjectures adopted by competing firms in the industry. Individual firms are assumed to make production and pricing decisions using "equilibrium" prices and quantities determined by aggregate demand and supply. Thus, the NEIO model focus on market macrostructure rather than market microstructure.

Auction models are also game-theoretic, but focus on market microstructure. Auction models can explain possible price markdowns due to bid-shading at auctions. Auctions are market institutions with an explicit set of rules that are used to elicit information, in the form of bids, from potential buyers regarding their willingness to pay for a good being auctioned (Krishna, 2002). Bidder's willingness to pay or valuation is a function of all information available to the bidder and the type of auction. Bidders' acting strategically may exert oligopsony power by shading their bids below their valuation, thereby depressing prices below price levels in competitive markets.

There are three basic auction models (Klemperer, 1999). Auctions are *private values* if each bidder has a unique valuation of the good being auctioned, and the valuation is private information to the bidder (e.g. an art object that is not intended for resale). Auctions are *common values* if the value of the auctioned good is the same for all bidders, but bidders have different private information about what that value is (e.g. an

oil lease). A prominent feature of auctions with common values is the winner's curse (overbidding). The winner's curse does not emerge in equilibrium since bidders recognize the potential "bad news" from winning an auction and adjust their bids accordingly. Valuations with both private and common aspects are called *affiliated* or *correlated*.

Structural Auction Model

Both parametric and nonparametric approaches have been used to structurally estimate auction models. We use the nonparametric approach since we do not have any prior knowledge about the distribution of bids (Jofre-Bonet and Pesendorfer, 2000). Our study draws on Guerre et al.'s (2000) nonparametric model to study competition in cattle procurement auctions. Guerre et al. derived the conditions for nonparametric identification of first-price sealed-bid auction models in the context of private values. Crespi and Sexton (2004) argue that cattle auctions resemble first-price sealed-bid auctions, particularly in the Texas Panhandle. Our study assumes first-price sealed-bid auctions with private values.

The assumption that packers have private values (PV) overlooks potential common values due to bidders' reliance on similar market information in determining the expected value of processed beef. Nevertheless, we use the PV assumption to keep the model simple. Furthermore, the PV assumption is not inconsistent with the factors influencing bidder's valuations in cattle procurement markets. To see why, consider each packer's valuation for a lot of cattle as the difference between the price of beef and the price of cattle. Then, to the extent processing costs are unique to each packer and known only to the packer, there is an PV component to bidders' valuation (Banerji and

Meenakshi, 2004). Furthermore, as long as bidders have the same information about the common aspects and place similar weight on it, then the PV assumption is not very restrictive (McAfee and McMillan, 1992).

To illustrate the auction model used in this study, we consider a cattle market with few packers purchasing cattle through a sequence of first-price sealed-bid auctions in the context of PV. Packers' valuation (R_{ij}) is defined as the price of processed beef at the time the *j*th cattle lot is purchased (p_j^r) minus the marginal cost (c_{ij}) of processing cattle into beef. That is $R_{ij} = p_j^r - c_{ij}$. Although competing packers may not know opponents' valuation, packers are assumed to know that all valuations *R*, including their own, come from a common distribution $G(\bullet)$, which is continuous with density $g(\bullet)$.

As mentioned previously, packer's valuation depends on the processing technology employed. Following Sexton (2000), we assume that beef packers use cattle and non-farm processing inputs to produce beef, q^r , using a quasi-fixed proportion processing technology. Such technology allows no substitution between cattle, q^f , and a vector of non-farm inputs, **v**, but may allow substitution between non-farm inputs. Processors' technology is represented as:

(2.1)
$$q^r = \min\{q^f / \gamma, g(\mathbf{v})\},$$

where $\gamma \leq q^{f}/q^{r}$ is the conversion factor between cattle and processed product.

In maximizing expected profits, π_i , the *i*th risk-neutral bidder faces the following maximization problem (Bajari and Hortaçsu, 2005):

(2.2)
$$\max_{p_{ij}^f} \pi_{ij} = q_{ij}^r (R_{ij} - p_{ij}^f) G(\varphi(p_{ij}^f))^{N_j - 1},$$

where *i* is a subscript for the *i*th packer, and *j* is a subscript representing the *j*th cattle lot, $R_{ij} = p_j^r - c_{ij}$ is packer *i*'s per-unit valuation of processed product q_{ij}^r , produced at processing cost c_{ij} , and sold at price p_j^r ; p_i^f is packer *i*'s dollar bid for cattle, $\varphi(p_{ij}^f)$ is the inverse of the equilibrium bid function, $G(\varphi(p_{ij}^f))^{N_j-1}$ is the probability that packer *i* wins the auction of the *j*th lot of cattle, and N_j is the number of packers bidding for the *j*th cattle lot.¹

The first-order condition for maximizing packer's profits is:

(2.3)

$$\frac{\partial \pi_{ij}}{\partial p_{ij}^{f}} = -q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} + q_{ij}^{r} (N_{j} - 1)(R_{ij} - p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} \frac{\partial G(\varphi(p_{ij}^{f}))}{\partial p_{ij}^{f}} = 0$$

$$= -q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} + q_{ij}^{r} (N_{j} - 1)(R_{ij} - p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} g(\varphi(p_{ij}^{f})) \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}} = 0$$

which can be rewritten as:²

(2.4)
$$p_{ij}^{f} = R_{ij} - \frac{F(p_{ij}^{f})}{f(p_{ij}^{f})(N_{j}-1)},$$

where $f(p_{ij}^{f}) = g(\varphi(p_{ij}^{f}))\partial\varphi(p_{ij}^{f})/\partial p_{ij}^{f}$ and $F(p_{ij}^{f}) = G(\varphi(p_{ij}^{f}))$ are bid density and distribution functions evaluated at p_{ij}^{f} .

Equation (2.4) shows that packers acting strategically could offer bids below packer's valuation R_{ij} . The bid markdown or bid-shading factor is represented by the second term of the right hand side of equation (2.4) (Hortaçsu, 2002). Notice that the bid-shading factor is inversely related to the number of packers N_j bidding for the *j*th lot of cattle, which may differ from the number of firms in the industry. The bid-shading factor approaches zero as the number of bidders on the *j*th cattle lot approaches infinity.

The NEIO Model

Characterization of a packer strategic behavior within the NEIO model is achieved via "conjectural variations" representing firm's best guess about competitors' response to a change in purchases of cattle (Appelbaum, 1982; Bresnahan, 1989). These conjectural variations are derived from the first-order condition of packer's profit maximization. Subsequent aggregation of firm behavior yields an industry supply equation incorporating industry-level conjectural variations.

To illustrate the concepts of the NEIO model, we consider the same beef processing industry described previously, and assume that farm input producers compete perfectly and supply cattle to packers via an inverse supply function represented as:

(2.5)
$$p^{f} = \sum_{j=1}^{J} p_{j}^{wf} / J = S(Y^{f} | \zeta),$$

where p^{f} is the market-level price of cattle, J is the total number of cattle lots sold, $p_{j}^{wf} = \max(p_{1j}^{f},...,p_{4j}^{f})$ is the winning bid on the *j*th cattle lot, Y^{f} is the total supply of cattle, and ζ is a vector of supply shifters.³ Notice that $Y^{f} = \sum_{j}^{J} y_{j}^{f}$, where y_{j}^{f} is an arbitrary cattle lot.

As with the auction model, packers' processing technology is assumed to be of Generalized Leontief form. For simplicity, the conversion factor to convert cattle into boxed beef is assumed to be one. Thus, $y_i^f = y_i^r = y_i$.

The profit maximization problem for packer *i* is represented as:

(2.6)
$$\max_{y_i^r} \pi_i = [p^r - p^f(Y^f)]y_i^r - C(y_i^r, \mathbf{v}).$$

where π_i is packer *i*'s profit, p^r is the retail price of beef, and $C(y_i^r, \mathbf{v})$ is the processing cost function for a representative packer. The first-order condition for maximizing equation (2.6) is:

$$\frac{\partial \pi_i}{\partial y_i^r} = p^r - \frac{dp^f(Y^f)}{dY^f} \frac{\partial Y^f}{\partial y_i^r} y_i^r - p^f - \frac{\partial C(y_i^r, \mathbf{v})}{\partial y_i^r} = 0.$$

Rearranging the first order condition yields:⁴

(2.7)
$$p^{r} = p^{f} [1 + \frac{(1 + \theta_{i})s_{i}}{\varepsilon_{s}^{f}}] + c(y_{i}^{r}),$$

where $c(y_i^r) = dC(y_i^r, \mathbf{v})/dy_i^r$ is packer *i*'s marginal cost of processing beef,

 $\varepsilon_s^f = (dY^f / dp^f)(p^f / Y^f)$ is the elasticity of cattle supply, $s_i = y_i^r / Y^r$ processor *i*'s market share, and $\theta_i = d\sum_{j\neq i}^n y_j^f / dy_i^r$ is packer *i*'s conjecture about rivals' responses to its change in purchases of cattle.

Customary with the NEIO model, an industry pricing equation is obtained from equation (2.7) after multiplying every term of (2.7) by each firm's market share s_i , and summing across all processors in the industry as:

(2.8)
$$\sum_{i}^{n} s_{i} p^{r} = \sum_{i}^{n} s_{i} p^{f} + \sum_{i}^{n} \left(\frac{(1+\theta_{i})s_{i}s_{i}}{\varepsilon_{s}^{f}} p^{f} \right) + \sum_{i}^{n} c(y_{i}^{r}).$$

Re-arranging equation (2.8) yields the industry pricing equation:

(2.9)
$$p^{r} = p^{f} [1 + \frac{(1 + \Theta)HHI}{\varepsilon_{s}^{f}}] + c(Y^{r}),$$

where $\Theta = \sum_{i} (y_{i}^{r})^{2} \theta_{i} / \sum_{i} (y_{i}^{r})^{2}$, is the industry weighted conjectural variation in the farm-input market, $c(Y^{r})$ is the market-level processing cost, and $HHI = \sum_{i} s_{i}^{2}$ is the Herfindahl index in the processing sector.

Equation (2.9) shows that the NEIO measure of oligopsony markdowns is directly related to both industry concentration (*HHI*) and weighted conjectural variation parameter (Θ), but inversely related to the elasticity of cattle supply. The market-level conjectural variation Θ is equal to zero under the Cournot-type competition, minus one under perfect competition, and one under perfect collusion.

The difference between oligopsony power from the NEIO model and oligopsony power from the structural auction model can be emphasized by separating the price markdown in equilibrium equations (2.4) and (2.9) as:

(2.10)
$$R_{ij} - p_{ij}^{f} = p_{j}^{r} - c_{ij} - p_{ij}^{f} = \frac{F(p_{ij}^{f})}{f(p_{ij}^{f})(N_{j} - 1)},$$

and,

(2.11)
$$p^{r} - c(Y^{r}) - p^{f} = \left[p^{f} \frac{(1 + \Theta)HHI}{\varepsilon_{s}^{f}}\right].$$

Equation (2.10) shows that the markdown derived from the auction theory,

 $F(p_{ij}^{f})/[f(p_{ij}^{f})(N_{j}-1)]$, depends on the number of bidders on a particular lot of cattle (N_{j}) and the distribution of bids. However, the markdown derived from the traditional NEIO model depends on the number of packers in the industry (n), since

 $HHI = \sum_{i} s_{i}^{2} = (y_{i}^{r} / Y_{i}^{r})^{2} = (1/n)^{2}, \text{ and the type of packer's conjectures about rivals}$ response to change in purchases of cattle $\theta_{i} = d \sum_{j \neq i}^{n} y_{j}^{f} / dy_{i}^{r}$, and the elasticity of cattle

supply. Clearly, these two models seek to measure different price markdowns.

An Integrated Model of Market Power

Previous sections outlined NEIO and auction models regarding potential oligopsony power in cattle procurement markets. The auction model considers transaction-level oligopsony markdowns, and the NEIO model considers market-level oligopsony markdowns. An integrated model is derived that shows the relationship between price markdowns from traditional NEIO models and bid-shading in auction models.

We first show how the presence of structural auction's bid-shading would affect price markdown measures using the NEIO approach. Then, we briefly describe why price markdowns estimated with auction models would not capture market-level markdowns. The model assumes that processors are fully aware of bid shading, and lower the market-level markdown to account for bid shading so that the total markdown is the same regardless of the size of bid shading.

To see the intuition behind our integrated model, let the (aggregate) average bidshading be represented as $\delta = \sum_{j=1}^{J} \{F(p_j^{wf})/[(f(p_j^{wf})(N_j - 1)]\}/J$, where $p_j^{wf} = \max(p_{1j}^f, ..., p_{4j}^f)$ is the winning bid on cattle lot *j*. Also, let the (aggregate) expected valuation of the winning bidder be defined as $w = \sum_{j=1}^{J} [E(\max(R_{1j}, ..., R_{4j}))]/J$, where *E* is the expectation operator, and R_{ij} (*i* = 1, ..., 4; *j* = 1,..., *J*) is packer *i*'s valuation of cattle lot *j*. The observed market "equilibrium" cattle price is represented as $p^f = \sum_{j=1}^{J} p_j^{wf}/J$, where *J* is the total number of cattle lots sold during an arbitrary time period. Recall that the "equilibrium" price p^f is equal to the expected valuation of the winning bidder (w) minus average bid-shading (i.e. $p^f = w - \delta$). Thus, if bid-shading is zero (i.e. $\delta = 0$) then $p^f = w$.

Our integrated model is an extension of the traditional NEIO model, but considers both potential bid-shading and market-level markdowns commonly measured with the traditional NEIO approach. Assuming that packers processing technology is of the Generalized Leontief form with the conversion factor of one in converting cattle (y_i^f) into boxed beef (y_i^r) (i.e. $y_i^f = y_i^r = y_i$), packer *i*'s profit maximization problem is represented as:

(2.12)
$$\max_{y_i^r} \pi_i = [p^r - (w(Y^f) - \delta)]y_i^r - C(y_i^r, \mathbf{v}).$$

where π_i is packer *i*'s profit, p^r is the retail price of beef, $w = w(Y^f)$ is the inverse cattle supply function, and $C(y_i^r, \mathbf{v})$ is the processing cost function for a representative packer. The first-order condition for maximizing equation (2.12) is:

$$\frac{\partial \pi_i}{\partial y_i^r} = p^r - \frac{dw(Y^f)}{dY^f} \frac{\partial Y^f}{\partial y_i^r} y_i^r - (w - \delta) - \frac{\partial C(y_i^r, \mathbf{v})}{\partial y_i^r} = 0.$$

Rearranging the first order condition yields:⁵

(2.13)
$$p^{r} = p^{f} + p^{f} \frac{(1+\theta_{i})s_{i}}{\varepsilon_{s}^{f}} + \delta \frac{(1+\theta_{i})s_{i}}{\varepsilon_{s}^{f}} + c(y_{i}^{r}),$$

where $c(y_i^r) = dC(y_i^r, \mathbf{v}) / dy_i^r$ is packer *i*'s marginal cost of processing beef,

 $\varepsilon_s^f = (dY^f / dw)(w/Y^f)$ is the total elasticity of cattle supply, $s_i = y_i^r / Y^r$ processor *i*'s market share, and $\theta_i = d\sum_{j\neq i}^n y_j^f / dy_i^r$ is packer *i*'s conjecture about rivals' responses to its change in purchases of cattle. Aggregation of equation (2.13) over the industry (see derivation of equation 2.9) yields:

(2.14)
$$p^{r} = p^{f} + p^{f} \frac{(1+\Theta)HHI}{\varepsilon_{s}^{f}} + \delta \frac{(1+\Theta)HHI}{\varepsilon_{s}^{f}} + c(Y^{r}).$$

Let $M(\Theta)$ equal $(1+\Theta)HHI/\varepsilon_s^f$. Then the integrated model represented by equation (2.14) can be re-written as:

(2.15)
$$p^r - p^f - c(Y^r) = p^f M(\Theta) + \delta M(\Theta).$$

The integrated model represented by equation (2.15) shows that the total price markdown, $p^r - p^f - c(Y^r)$, includes the traditional NEIO market-level markdown $(p^f M(\Theta))$ plus some weighted bid-shading $(\delta M(\Theta))$. The model also shows that price markdowns estimated with the traditional NEIO model could capture some bid-shading if $cov(\delta \frac{HHI}{\varepsilon_s^f}, p^f \frac{HHI}{\varepsilon_s^f})$ is not zero. However, the NEIO approach would underestimate the total markdown since $\delta HHI/\varepsilon_s^f$ and $p^f HHI/\varepsilon_s^f$ are likely not perfectly correlated.

Also, policy implications implied by the integrated model differ from the traditional NEIO model, which focuses mainly on packers' strategic behavior at the market-level.

The model represented by equation (2.15) also suggests that any market-level markdowns are reduced by the full amount of bid-shading at auctions. But this is not the only possibility. The two effects could be partially additive where increased bid shading would result in a larger total markdown.

Market-level markdowns commonly measured with the NEIO model $(p^f M(\Theta))$ also affects packers' bid shading. This effect can be shown by rearranging the total markdown represented by equation (2.15) as:

$$\delta = \frac{1}{M(\Theta)} (p^r - p^f - c(Y^r)) - p^f.$$

Notice that the expected valuation of the winning bidder can be represented as

 $w = \delta + p^{f} = (p^{r} - p^{f} - c(Y^{r})) / M(\Theta).$ But since *w* was also defined as $w = \sum_{j=1}^{J} [E(\max(R_{1j}, ..., R_{4j}))] / J, \text{ it follows that the expected valuation of the winning}]$

bidder is
$$w = \delta + p^f = (p^r - p^f - c(Y^r) / M(\Theta) = \sum_{j=1}^J [E(\max(R_{1j}, ..., R_{4j}))] / J$$
. Thus,

market-level markdowns affect bid shading through *w*, the expected valuation of the winning bidder. The expected valuation of the winning bidder is directly related to the parameters of the distribution of packers valuation $G(\bullet)$. In the end, the valuations (R_{ij}) are reduced by the additional market-level market power.

Data

An experimental game was played to generate cattle procurement data used to estimate price markdowns with both NEIO and auction models, and to test the traditional NEIO model against the an auction model. The experimental game allows knowing packers' "true" profits and recording all bids, which is not possible in real world cattle markets. Data were generated from a five-hour evening workshop using the *Fed Cattle Market Simulator* (FCMS) (Hogan et al., 2003; Ward, 2005) in February, 2006. The FCMS simulates a market for fed cattle that mimics the real-world cattle procurement market. Some participants in the FCMS play the role of feedlot managers while others play the role of meatpackers.

The participants in the experiments were primarily undergraduate students majoring in agricultural economics. The students were organized in four packer teams (each with four members) and eight feedlot manager teams (each with 3 or 4 members).

In addition, one "observer" was allocated to each feedlot with the exclusive task of recording bids submitted by packers, both winning and losing bids. The data recorded at each feedlot consisted of price and quality of cattle sold, and identity of feedlots and buyers.

During the experimental game, packer and feedlot teams are instructed to maximize profits. Both packers and feedlot managers were instructed to buy and sell cattle for profit. Competition among teams was stimulated by paying a \$40 participation fee per person with the opportunity to win more or lose part of the fee based on financial performance during the game. Packers' gain averaged about \$3.65 per hundredweight of dressed beef. No packer team lost money during the game.

Each member of a packer team was assigned to a feedlot and instructed to act as a regional buyer, just like in real cattle procurement markets. This was intended to allow enough time for packers to inspect and submit bids for cattle among spatially dispersed feedlots. Each trading period lasted about ten minutes and was called a "week." Feedlots and meatpacking managers were provided with market-level information to help them make trading decisions. The information provided included the volume of cattle trade, cattle placed on feed, and the wholesale price of processed beef in the previous trading period.

A total of 592 transactions were made during fourteen trading weeks after allowing for a training period of two weeks (worth 77 transactions). After the first seven weeks of cattle trades, two mergers were simulated. Packer 1 merged with Packer 2, and Packer 3 merged with Packer 4. These mergers represented the smallest packers (1 and 2) and the largest packers (3 and 4). Overall, the structure of the game remained

essentially the same after the mergers, except that there were two bigger packers instead of four smaller ones.

Table II-1 shows descriptive statistics of the variables used in the empirical analysis, and table II-2 reports weekly average profits per packer before and after the mergers. Table II-2 shows that all packers made positive profits during the experimental game and, therefore, the winners' curse does not appear to be important *on average* (Meyer, 1988).

Empirical Procedures

The empirical procedures used to estimate price markdowns with structural auction and NEIO models are described in this section. Markdowns estimated with these two models are subsequently compared with the markdowns estimated directly from the data. This section also describes the empirical procedures used to test the NEIO model against the auction model.

Estimation with the Structural Auction Model

We now outline the procedures used to estimate packer's bid-shading using the structural auction model represented by equation (2.10). The estimation considers the number of potential bidders rather than the actual number of bidders. This was done due to the presence of numerous transactions where only one bidder submitted a bid, which would preclude estimation of bid-shading with equation (2.10).

Equation (2.10) shows that packer's bid-shading is the ratio of the cumulative distribution of bids $F(p_{ij}^{f})$ to the product between bid density function $f(p_{ij}^{f})$ and the

number of bidders on a lot of cattle minus one $(N_j - 1)$. Packers' bid-shading are estimated nonparametrically because we do not know the true shape of the distribution of bids (Jofre-Bonet and Pesendorfer, 2000). Following Guerre et al. (2000), the estimates of bid distribution and density functions are obtained via the empirical distribution $\hat{F}(p_{ij}^{f})$ and kernel density estimator $\hat{f}(p_{ij}^{f})$, respectively as:

(2.17)
$$\hat{F}(p_{ij}^{f}) = \frac{1}{NJ} \sum_{i=1}^{N} \sum_{j=1}^{J} I(p_{ij}^{f} \le p^{f}),$$

(2.18)
$$\hat{f}(p_{ij}^{f}) = \frac{1}{NJh} \sum_{i=1}^{N} \sum_{j=1}^{J} K\left(\frac{p^{f} - p_{ij}^{f}}{h}\right),$$

where $I(\bullet)$ is an indicator function that takes the value of one if $p_{ij}^f \le p^f$ and zero otherwise, *h* is a *bandwidth* defining the size of the "neighborhood" around an arbitrary bid p^f , p_{ij}^f is the *j*th bid in the interval $(p^f - h, p^f + h)$, *J* is the total number of cattle lots, and $K(\bullet)$ is the kernel density function, which assigns weights to every bid in the neighborhood of p^f .

The kernel density function defined by equation (2.18) is estimated assuming a Gaussian kernel function as:

(2.19)
$$K(u) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}u^2), \text{ where } u = \left(\frac{p^f - p_{ij}^f}{h}\right).$$

Previous studies indicate that while the choice of the kernel functional does not affect results in practice, the choice of the bandwidth (*h*) may affect results (DiNardo and Tobias, 2001; Härdle et al., 2004). Sheather (2004, p.596) recommends the Sheather-Jones plug-in method (SJPI) due to good performance relative to other methods. The bandwidth with SJPI is:

$$(2.20) h = \hat{\sigma} \left(\frac{4}{3NJ}\right)^{1/5}$$

where $\hat{\sigma}$ is the sample standard deviation of the total bids and *NJ* is the number of bids in the sample data. The kernel density function is estimated using the KDE Procedure in SAS 9.1. The option METHOD = SJPI in the KDE Procedure is used to request bandwidths computed using the SJPI.

Then, estimates of bid shading for each successful transaction using a slightly modified version of equation (2.10) as:

(2.21)
$$\hat{p}_{j}^{r} - \hat{c}_{j} - \hat{p}_{j}^{wf} = \hat{\delta}_{j} = \frac{\hat{F}(p_{j}^{wf})}{\hat{f}(p_{j}^{wf})(N-1)},$$

where $p_j^{wf} = \max(p_{1j}^f, ..., p_{4j}^f)$ is the winning bid on the *j*th cattle lot.

Estimation with the Traditional NEIO Model

We now describe the procedures used to estimate price markdowns with the traditional NEIO model. The estimation with the NEIO model is based on equation (2.11). To derive $C(Y^r)$ in equation (2.11) it is necessary to define packers' processing cost equation. Following Azzam (2001), packers are assumed to use a flexible processing technology $C(y_i^r, \mathbf{v})$ represented by the Generalized Leontief cost function as:

(2.22)
$$C(y_i^r, \mathbf{v}) = y_i^r \sum_k \sum_m \alpha_{km} (v_k v_m)^{1/2} + (y_i^r)^2 \sum_m \beta_m v_m,$$

where y_i^r is packer *i*'s output, **v** is a price vector of non-farm inputs such as labor and capital, and α_{km} , λ_k , and β_m are parameters to be estimated. Notice that all non-farm inputs **v** used for processing beef remain constant in the experimental market. Therefore, packer's processing cost represented by (2.22) reduces to $C(y_i^r) = \alpha_{km} y_i^r + \beta_m (y_i^r)^2$, which is a quadratic cost function. Packers' actual average cost function in the game is also quadratic.

The industry marginal cost $c(Y^r)$, required to estimate industry-level markdowns represented by equation (2.15), is obtained in the following way. First, we differentiate packer's processing cost equation (2.22) with respect to output to get a firm-level marginal cost, as $c(y_i^r) = \partial C(y_i^r, \mathbf{v}) / \partial y_i^r = \alpha_{km} + 2\beta_m y_i^r$. For convenience, packers' marginal cost can be represented as:

$$(2.23) c(y_i^r) = 2\beta_m y_i^r.$$

Next, we obtain the industry marginal cost equation by multiplying every term of (2.23) by each firm's market share s_i , and summing across all processors in the industry as:

$$\sum_{i}^{n} s_i c(y_i^r) = 2\beta_m \sum_{i}^{n} s_i y_i^r,$$

which can be re-arranged to yield the industry marginal cost function $c(Y^r)$ as:⁶

$$(2.24) c(Y^r) = 2\beta_m Y^r HHI$$

Lastly, the industry pricing equation used to estimate oligopsony power is obtained by rearranging equation (2.11) after replacing $c(Y^r)$ with equation (2.24) as:

(2.25)
$$p^{r} = p^{f} \left[1 + \frac{(1+\Theta)HHI}{\varepsilon_{s}^{f}}\right] + 2\beta_{m}Y^{f}HHI.$$

Empirical estimation of equation (2.25) also requires knowing the elasticity of cattle supply. The elasticity of cattle supply could be obtained from a cattle supply equation, which is estimated jointly with equation (2.25). However, a system of equations containing equation (2.25) and a supply equation was not well identified since

there was no variable in the pricing equation that was not in the cattle supply equation. Following Paul's (2001) suggestion, equation (2.25) was estimated alone assuming several values for cattle supply elasticity (0.2, 0.4, 0.8 and 1). Specifically the following equation was estimated:

(2.26)
$$p_{t}^{r} = a_{0} + p_{t}^{f} \left[1 - \frac{(1 + \Theta)HHI_{t}}{\varepsilon_{s}^{f}}\right] + a_{1}2HHI_{t}(Y_{t}^{f} / SHOW_{t}) + v_{t},$$

where p_t^r is the average price of boxed beef in week t, p_t^f is the average cattle price of dressed beef, *SHOW*_t is the total inventory of cattle in the show list, a_0 , a_1 , a_2 and Θ are parameters to be estimated, and v_t is a error term. To consider changes in total inventory of cattle over time, we use the ratio of total marketings (Y_t^f) to total inventory of cattle (*SHOW*_t) rather than the marketings alone (Schroeter and Azzam, 1991). To account for possible measurement errors and endogeneity of total marketings (Y_t^f) that could lead to inconsistent OLS because $E[v_t x_t] \neq 0$, equation (2.26) is estimated via nonlinear twostage least squares (Zellner and Theil, 1962).

An Indirect Test with an Encompassing Model

Auction and NEIO theories are tested indirectly using a nonnested test. The test is indirect because we do not use the integrated model represented by equation (2.15) to test the two theories. Estimating the integrated model represented by equation (2.15) would first require estimating the bid-shading factor, δ , represented by equation (2.21). But numerous transactions had only one bidder on a cattle lot, which precluded estimation of transaction-level bid-shading using equation (2.21). Therefore, we decided to develop an indirect test. The indirect test is based on a reduced form encompassing regression of price spreads on number of bidders and market-level concentration. We test the hypothesis that market concentration affects price spreads against the hypothesis that the number of bidders affects price spreads. If the number of bidders is statistically significant, then the traditional NEIO theory is rejected. The NEIO theory clearly implies that it is market concentration that should matter. One weakness of this approach is that the structural auction theory is ambiguous as to whether it is the number of bidders or the number of potential bidders that matters. We estimate the structural auction model using the number of potential bidders (i.e. number of firms) rather than the number of actual bidders because of data limitations. As a result of data limitations, the structural auction model might capture market-level markdowns (i.e. the same effect measured with the NEIO model) rather than the intended transaction-level markdowns because the number of firms is correlated with market concentration (*HHI*).

The encompassing model (M3) nests models M1 and M2. Both M1 and M2 are single-equation regressions of the spreads between wholesale beef prices and winning bids on a set of explanatory variables. Model M1 includes the number of bidders, but not the Herfindahl index, and model M2 includes the Herfindahl index, but not the number of bidders. To account for weekly changes in demand and supply of cattle, which are observed imperfectly within the experimental cattle market, an additional error term is appended to model (M3) to capture time random effects as:

$$M3: \quad p_{t}^{r} - p_{jt}^{wj} = \omega_{0} + \omega_{1}shwlst_{t} + \omega_{2}todem_{t} + \omega_{3}fdlt1_{jt} + \omega_{4}fdlt2_{jt} + \omega_{5}fdlt3_{jt} + \omega_{6}fdlt4_{jt} + \omega_{7}fdlt5_{jt} + \omega_{8}fdlt6_{jt} + \omega_{9}fdlt7_{jt} + \omega_{10}GenM_{jt} + \omega_{11}GenH_{jt} + \omega_{12}wt1150_{jt} + \omega_{13}wt175_{jt} + \omega_{14}bid1_{jt} + \omega_{15}bid2_{jt} + \omega_{16}bid3_{jt} + \omega_{17}HHI_{t} + \eta_{t} + \varepsilon_{jt},$$

where subscript *j* represents an arbitrary lot of cattle, subscript *t* indicates a week within which the *j*th lot is sold, p_t^r is beef price, p_{jt}^{wf} is winning bid, *todem*_t is total demand for cattle, fdlt1_{jt}, fdlt2_{jt}, fdlt3_{jt}, fdlt4_{jt}, fdlt5_{jt}, fdlt6_{jt}, and fdlt7_{jt} are zero-one indicator variables that equal one if the cattle are bought from feedlots 1, ..., 7, respectively; *shwlst*_t is the inventory of cattle available for sale in a given week, $wt150_{jt}$, and $wt175_{jt}$ are zero-one indicator variables that equal one if a steer's weight is 1500, and 1175 lbs., respectively; $GenM_{it}$, and $GenH_{it}$ are zero-one indicator variables that equal one if the generic type of carcass quality is medium, and high, respectively; *bid1_{it}*, *bid2_{it}*, and *bid3_{it}* are zero-one indicator variables that equal to one if there were one, two, or three bidders on the lot; *HHI*_t is the sum of squares of firm shares and measures industry concentration, the ω_{it} 's are parameters to be estimated, $\eta_t \sim N(0, \sigma_{\eta}^2 I_n)$ is a week-specific random error term to capture imperfectly measured changes in weekly demand and supply of cattle, $\varepsilon_{jt} \sim N(0, \sigma_{\varepsilon_{jt}}^2 I_n)$, is an observation-specific error term that accounts for possible heteroskedasticity inherent to time-series cross-sectional data, with $\sigma_{\varepsilon_u}^2 = exp(b_0 + b_0)$ $b_1 shwlst_t + b_2 todem_t$) and $cov(\varepsilon_{jt}, \eta_t) = 0$. The variance components model (M3) was estimated via maximum likelihood (ML) using the NLMIXED Procedure in SAS 9.1 (SAS 2001-2003).

The independent variables used in the encompassing model *M*3 are similar to the variables used by Ward (2005), excluding a variable, unique to Ward's study, measuring the effect of the interaction between pricing method and cattle genetic type. The indicator variables for number of bidders on a cattle lot, Herfindahl index, and the week-

specific error term are unique to our study. Furthermore, while Ward's study focused on packer's choice of pricing methods, this study focuses estimating price markdowns.

There are two null hypotheses of interest in model *M*3. The first null hypothesis is that the coefficients of *bid*1, *bid*2 and *bid*3 are jointly zero (H_{01} : $\omega_{14} = \omega_{15} = \omega_{16} = 0$). The second null hypothesis is that the coefficient for HHI_t is zero (H_{02} : $\omega_{17} \le 0$). If both H_{01} and H_{02} are rejected, then number of bidders and the number of firms contain unique information, and the general model (*M*3) is favored over models *M*1 and *M*2. If both H_{01} and H_{02} are not rejected, then the number of bidders and the number of firms contain the same information, and either model *M*1 or model *M*2 could be used to explain the pricing behavior in the experimental cattle market. If only H_{01} is rejected then model *M*1 is favored to model *M*2, while if only H_{02} is rejected model *M*2 is favored to model *M*1.

Empirical Results

Price markdowns estimated with structural auction and traditional NEIO models are shown in tables II-3 and II-4, respectively. The structural auction's average markdown for all bidders is \$3.37 per cwt while the average markdown obtained with the traditional NEIO approach is \$2.7 per cwt. Both the NEIO's and the structural auction's estimates are close to the "true" markdown of \$3.64 per cwt, obtained directly from the data (table II-2).⁷ Results suggest that neither model is superior to the other in explaining price markdowns in the game.

Maximum likelihood estimates of the encompassing model represented by equation (2.13) are shown in table II-5. The most important estimates are the coefficient of the Herfindahl index ($\hat{\omega}_{17} = 11.95$), and the coefficient of indicator variables when

there is one bidder ($\hat{\omega}_{14} = 0.47$), two bidders ($\hat{\omega}_{15} = 0.38$), or three bidders ($\hat{\omega}_{16} = 0.28$) bidding on lot of cattle. As expected, the coefficients of the Herfindahl index (*HHI*_t), and the coefficients of the number of bidders on a lot of cattle are both positive.

The coefficient of HHI_t (\$11.95) suggests that the increase in market concentration through mergers from 0.264 to 0.512 increased the price spread by \$2.90 (\$11.5[0.512-0.264]). This firm effect is about 28 times bigger than the effect of increasing concentration by reducing the number of bidders by one, when three or two bids are obtained. Thus, the number of firms is more important than the number of bidders in explaining cattle price markdowns.

A joint likelihood ratio test and a one-tailed *t*-test are used to test the hypothesis that the number of bidders affects price spreads against the hypothesis that market concentration affects price spreads. The null hypothesis that the number of bidders affects price spreads $(H_{01}: \omega_{14} = \omega_{15} = \omega_{16} = 0)$ is rejected at the 5% level based on a likelihood ratio (LR) test, since LR = 2[Log Likelihood *M*3 – Log Likelihood *M*1] = $10.2 > \chi^2_{3,0.05} = 5.99$. The null hypothesis that the Herfindahl index is zero $(H_{02}: \omega_{17} \le 0)$ is also rejected at the 5% level based on a *p*-value of 0.0327 for a one-tailed *t*-test.⁸ Thus, neither traditional NEIO nor structural auction models sufficiently explain packers' price markdown behavior in the cattle market.⁹ Both the number of bidders and the number of firms do contain some unique information about pricing behavior in the experimental cattle market, which suggest that an integrated model containing both number of bidders and number of firms would be more appropriate.

Conclusions

Many recent studies evaluated potential market power in U.S. cattle procurement markets. These studies used either the traditional NEIO model or the auction model. While the NEIO model seeks to measure price distortions due to industry-level imperfect competition (i.e. focusing on macrostructure), the auction models consider price distortion from bid shading at local auctions (i.e. focusing on microstructure).

This study seeks to integrate the two theories. Theoretical results show that the NEIO measures will include some bid-shading, but auction measures do not include industry-level markdowns. Theoretical results suggest that both traditional NEIO and auction models may miss some of the total markdown.

Both the NEIO and structural auction models give predictions of price markdowns that are close to the actual in an experimental auction setting. Since the estimates are close to the actual, comparing predicted and actual profits leaves both theories viable.

A regression of price spreads against a set of explanatory variables showed that the number of firms in the experimental game has a bigger effect than the number of bidders on a lot of cattle in explaining price markdowns in the experimental game. Since results showed that the number of bidders on a particular lot of cattle contains some unique information it means that both NEIO and auction models are incomplete. The number of firms being more important than the number of bidders may seem to favor the NEIO approach. However, hypothesis tests indicated that neither traditional NEIO nor auction models sufficiently explain packers' markdowns in the experimental cattle market. This finding suggests that a model integrating both market-level and transaction-

level measures of markdowns would be more adequate to explain the markdowns in the game. In general, empirical results were consistent with theoretical results.

The structural auction model is ambiguous as to whether it is the number of actual bidders or the number of potential bidders that matters. Even though a feedlot may have only obtained one bid, packers may base their bid on the number of potential bidders (i.e. number of firms in the industry) rather than number of actual bidders since the latter is often unknown to an individual bidder at the time of bid submission. But since feedlots have the option of obtaining additional bids and may be able to recognize a good bid, the structural auction model could allow for a greater importance of number of firms.

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Notes

- Given that packers draw bids from a common distribution G(•), the probability of wining a bid for an individual packer among N_j packers is G(•)^{N_j-1}. Notice that for every p^f ∈ [p^f, p^f] = [R, s(R)], G(R) = G(s⁻¹(p^f)) = G(φ(p^f)) = F(p^f) = Pr(R_{ij} ≤ φ(p^f)) = Pr(p^f_{ij} ≤ p^f) = F(p^f), where s⁻¹ is the inverse equilibrium strategy, p^f is an arbitrary equilibrium bid, and s⁻¹(b) = φ(b) = R is an arbitrary valuation. The distribution F(•) is continuous and increasing within its support [R, s(R)].
- 2. Equation (2.4) is derived from equation (2.2) as:

$$\begin{split} \frac{\partial \pi_{ij}}{\partial p_{ij}^{f}} &= -q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} \\ &+ q_{ij}^{r} (N_{j}-1) (R_{ij}-p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} \frac{\partial G(\varphi(p_{ij}^{f}))}{\partial p_{ij}^{f}} = 0 \\ &= -q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} + q_{ij}^{r} (N_{j}-1) (R_{ij}-p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} g(\varphi(p_{ij}^{f})) \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}} = 0 \\ &= > q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} + q_{ij}^{r} (N_{j}-1) (R_{ij}-p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} g(\varphi(p_{ij}^{f})) \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}} = 0 \\ &= > q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-1} = q_{ij}^{r} (N_{j}-1) (R_{ij}-p_{ij}^{f}) G(\varphi(p_{ij}^{f}))^{N_{j}-2} g(\varphi(p_{ij}^{f})) \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}} \\ &= > \frac{q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-2} (N_{j}-1)}{q_{ij}^{r} G(\varphi(p_{ij}^{f}))^{N_{j}-2} (N_{j}-1)} = (R_{ij}-p_{ij}^{f}) g(\varphi(p_{ij}^{f})) \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}} \\ &= > \frac{G(\varphi(p_{ij}^{f}))^{N_{j}}}{(N_{j}-1) g(\varphi(p_{ij}^{f}))} \frac{\partial \varphi(p_{ij}^{f})}{\partial p_{ij}^{f}}} = (R_{ij}-p_{ij}^{f}), \end{split}$$

which can be rewritten as:

$$p_{ij}^{f} = R_{ij} - \frac{F(p_{ij}^{f})}{f(p_{ij}^{f})(N_{j} - 1)}.$$

- 3. Notice that market level (equilibrium) price of cattle p^f in (2.5) is not equal to the transaction level price of cattle p^f_{ij} in (2.4). The former is the average of winning bids in J cattle auctions (transactions), while the latter includes losing bids. Thus p^f = ∑^J_{j=1} p^{wf}_j / J, where p^{wf}_j is the winning bid for the *j*th lot of cattle.
- 4. Equation (2.7) is derived from equation (2.6) as:

$$\begin{split} &\frac{\partial \pi_{i}}{\partial y_{i}^{r}} = p^{r} - \frac{dp^{f}(Y^{f})}{dY^{f}} \frac{\partial Y^{f}}{\partial y_{i}^{r}} y_{i}^{r} - p^{f} - \frac{\partial C(y_{i}^{r}, \mathbf{v})}{\partial y_{i}^{r}} = 0 \\ & \Longrightarrow \quad p^{r} = \frac{dp^{f}(Y^{f})}{dY^{f}} \frac{Y^{f}}{p^{f}} \frac{p^{f}}{Y^{f}} y_{i}^{r} \frac{\partial Y^{f}}{\partial y_{i}^{r}} + p^{f} + \frac{\partial C(y_{i}^{r}, \mathbf{v})}{\partial y_{i}^{r}} = 0 \\ & \Longrightarrow \quad p^{r} = \frac{dp^{f}(Y^{f})}{\frac{dY^{f}}{1/\varepsilon_{s}^{f}}} \frac{Y^{f}}{p^{f}} \frac{y_{i}^{r}}{y_{i}^{r}} p^{f} \frac{\partial Y^{f}}{\partial y_{i}^{r}} + p^{f} + \frac{\partial C(y_{i}^{r}, \mathbf{v})}{\partial y_{i}^{r}} = 0, \end{split}$$

which can be rearranging as:

$$p^{r} = p^{f} \left[1 + \frac{(1+\theta_{i})s_{i}}{\varepsilon_{s}^{f}}\right] + c(y_{i}^{r}).$$

5. Equation(2.13) is derived from equation(2.12) as:

$$\frac{\partial \pi_i}{\partial y_i^r} = p^r - \frac{dw(Y^f)}{dY^f} \frac{\partial Y^f}{\partial y_i^r} y_i^r - (w - \delta) - \frac{\partial C(y_i^r, \mathbf{v})}{\partial y_i^r} = 0.$$

$$\Rightarrow p^r = \frac{dw(Y^f)}{dY^f} \frac{Y^f}{w} \frac{w}{Y^f} y_i^r \frac{\partial Y^f}{\partial y_i^r} + (w - \delta) + \frac{\partial C(y_i^r, \mathbf{v})}{\partial y_i^r} = 0.$$

$$=> p^{r} = \frac{dp^{f}(Y^{f})}{dY^{f}} \frac{Y^{f}}{w} \frac{y^{r}_{i}}{\sum_{s_{i}}^{s}} \frac{W}{p^{f}} \frac{\partial Y^{f}}{\partial y^{r}_{i}} + \underbrace{(w-\delta)}_{p^{f}} + \frac{\partial C(y^{r}_{i}, \mathbf{v})}{\frac{\partial y^{r}_{i}}{c(y^{r}_{i})}} = 0,$$
$$=> p^{r} = (p^{f} + \delta) \frac{(1+\theta_{i})s_{i}}{\varepsilon_{s}^{f}} + p^{f} + c(y^{r}_{i}),$$

which can be rearranging as:

$$p^{r} - c(y_{i}^{r}) - p^{f} = (p^{f} + \delta) \frac{(1 + \theta_{i})s_{i}}{\varepsilon_{s}^{f}}$$

6. Equation (2.24) is derived from equation (2.23) as:

$$c(y_i^r) = 2\beta_k y_i^r \implies \sum_i^n s_i c(y_i^r) = 2\beta_k \sum_i^n s_i y_i^r \implies \sum_i^n s_i c(y_i^r) = 2\beta_k \sum_i^n s_i \frac{y_i^r}{Y_i^r} Y^r$$
$$\implies \sum_i^n s_i c(y_i^r) = 2\beta_k \sum_i^n s_i^2 Y^r \implies \sum_i^n s_i c(y_i^r) = 2\beta_k \sum_i^n s_i^2 Y^r,$$

which can be re-arranged to yield the industry marginal cost function represented by equation (2.24) as:

$$c(Y^r) = 2\beta_k Y^r HHI.$$

- 7. Price markdowns obtained directly from game data and price markdowns estimated with the structural auction model show that the average price spread across packers after the mergers is two to three times bigger than the price spreads before the mergers. The game data did not contain enough observations to estimate price markdowns before and after mergers with the NEIO approach since data aggregated by week contained only 14 observations.
- 8. This *p*-value for the one-tailed test of H_{02} : $\omega_{17} \le 0$ against $H_{A2} > 0$ is obtained by dividing the *p*-value for the two-tailed test by two (0.0654/2). Notice that if the sign of the coefficient had the opposite sign from the sign implied by the relevant research

hypothesis of $H_{A2} > 0$ (i.e. if the coefficient of HHI_{jt} were negative rather than positive) then the *p*-value would be computed as 1 - 0.0654/2.

Variable	Mean	S D		
Before Merger (four firms and four firms, $N = 302$)				
Average cattle weight (cwt of dressed beef)	721.6	1.7		
Average cattle price (\$/cwt of dressed beef)	128.8	0.5		
Average beef price (\$/cwt of dressed beef)	139.0	2.5		
Inventory of cattle (pens)	113.4	4.2		
Total demand of cattle (pens)	38.3	4.4		
Herfindahl index	0.26	0.009		
After Merger (four firms and four fir	rms, N = 290)			
Average cattle weight (cwt of dressed beef)	723.6	2.2		
Average cattle price (\$/cwt of dressed beef)	118.7	1.9		
Average beef price (\$/cwt of dressed beef)	135.4	2.8		
Inventory of cattle (pens)	131.2	8.8		
Total demand of cattle (pens)	41.7	3.5		
Herfindahl index	0.51	0.01		

Table II-1.Mean and Standard Deviation of the Variables from the Experimental
Market

Week/Average	Packer 1	Packer 2	Packer 3	Packer 4	
before merger ($N = 302$)					
Week 23	1.79	2.86	3.94	3.68	
Week 24	6.52	3.86	8.59	1.62	
Week 25	2.29	4.31	2.52	0.62	
Week 26	0.56	0.62	-0.76	-3.19	
Week 27	5.70	4.51	5.72	1.85	
Week 28	3.75	5.12	4.76	1.62	
Week 29	0.26	-0.29	0.38	1.19	
Week 30	-1.52	-0.10	-1.23	2.00	
Average before mergers	2.42	2.61	2.99	1.17	
	after merger	(N = 290)			
Week 31	7.61	1.49	4.38	4.64	
Week 32	2.95	0.81	1.80	-2.88	
Week 33	9.36	7.33	7.51	4.47	
Week 34	10.54	8.30	5.03	7.66	
Week 35	6.03	4.87	5.93	5.24	
Week 36	4.19	2.19	6.13	6.26	
Week 37	4.67	6.61	5.81	6.15	
Average after mergers	6.48	4.51	5.23	4.51	
Average profit per packer for both time periods	4.33	3.51	4.04	2.74	
Average profit across all packers for both time periods	3.65				

Table II-2.Weekly Profits for Packers in the Experimental Cattle Procurement
Market (\$/cwt of dressed weight)

Packer/Average	Price markdown	Interquartile range	Herfindahl index
before merger (optimal bandwie	dth = 0.36)	
Packer 1	1.06	1.15	
Packer 2	1.33	0.78	
Packer 3	2.77	0.81	
Packer 4	2.41	1.12	
Average across four packers	2.00	0.91	0.264
after merger (o	optimal bandwid	th = 0.69)	
Packers 1&2	5.78	1.10	
Packers 3&4	3.89	2.26	
Average across two packers	4.71	1.54	0.512
Average across all packers for both time periods	3.37	-	

Table II-3. Structural Auction Estimates of Cattle Price Markdowns

Note: Optimal bandwidths were selected using the Sheather-Jones plug in method (Sheather, 2004).

Parameter	Symbol	Estimate	S D	p-value
Industry conjectural variation	Θ	-0.94	0.19	0.0004
Processor's pricing equation intercept	a_0	8.98	2.30	0.0025
Coefficient for packer's marginal cost	a_1	13.00	33.70	0.39
Price markdown		2.7		

 Table II-4.
 Nonlinear Two-Stage Least Squares Estimates of the NEIO Model

		Standard		
Parameter	Estimate	error	t-value	<i>p</i> -value
Intercept	2.91	8.25	0.35	0.7291
Cattle inventory (shwlst)	-0.006	0.07	-0.08	0.9343
Total demand (todem)	0.13	0.12	1.04	0.3129
Cattle from Feedlot 1 (<i>fdlt</i> 1)	0.17	0.19	0.87	0.3979
Cattle from Feedlot 2 (<i>fdlt</i> 2)	-0.06	0.20	-0.32	0.7522
Cattle from Feedlot 3 (<i>fdlt3</i>)	-0.59	0.19	-3.05	0.0076
Cattle from Feedlot 4 (<i>fdlt</i> 4)	0.24	0.19	1.22	0.2401
Cattle from Feedlot 5 (<i>fdlt5</i>)	-0.83	0.20	-4.22	0.0006
Cattle from Feedlot 6 (<i>fdlt</i> 6)	-0.41	0.20	-2.05	0.0575
Cattle from Feedlot 7 (<i>fdlt</i> 7)	0.44	0.21	2.1	0.0515
Medium generic carcass (GenM)	1.25	0.12	10.82	< 0.0001
High generic carcass (GenH)	3.03	0.13	22.7	< 0.0001
Cattle sold at 1500 lbs. (wt150)	1.07	0.19	5.74	< 0.0001
Cattle sold at 1500 lbs. (wt175)	3.92	0.31	12.62	< 0.0001
Herfindahl index (HHI)	11.95	6.04	1.98	0.0654
Indicator for one bidder (bid1)	0.47	0.44	1.06	0.3053
Indicator for two bidders (bid2)	0.38	0.22	1.78	0.0947
Indicator for three bidders (<i>bid</i> 3)	0.28	0.15	1.86	0.0811
Intercept of the variance equation	0.44	0.87	0.51	0.619
Coefficient of cattle inventory in the variance equation	-0.02	0.01	-2.55	0.0215
Coefficient of total demand in the variance equation	0.05	0.01	3.32	0.0043
Estimate of random effects for week	4.38	1.52	2.88	0.011
-2 Log Likelihood	1916.6			

Table II-5.Maximum Likelihood Parameter Estimates and Standard Errors of
the Encompassing Model

Appendix A: Institutional Review Board Approval for Research with Human **Subjects**

Oklahoma State University Institutional Review Board

Date:	Friday, February 17, 2006
IRB Application No	AG0623
Proposal Title:	Testing for Market Power in Cattle Procurement Markets: A Nonparametric Approach
	Freemat
Processed as:	Exempt
	Lith Building (a): Approved Brotocol Expires: 2/16/2007

Status Recommended by Reviewer(s): Approved

Principal Investigator(s Chanjin Chung 322 Ag Hall Stillwater, OK 74078

Emilio Tostao 535 Ag Hall Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

- Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
 Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
 Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
 Notifie the IRB efficie is writing when when events are complete

- Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 415 Whitehurst (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Sue C. Jacobs Chair Institutional Review Board

	OSU
Insi	itutional Review Board
App	proved 2/11/06
Exp	ires <u>2116107</u>
Initi H	als 0/

PLAY THE <u>PACKER-FEEDER</u> SIMULATION FOR REAL MONEY

We are recruiting people to play the OSU Packer-Feeder simulation on two evenings as a part of a research project. Student participants will be asked to role-play in feedlot or packer teams in the simulation to the best of their ability.

Participants will be paid a \$40 participant fee with the opportunity to win more or lose part of the fee based on performance in the game. Participants must commit to be available for four hours each of two consecutive Monday evenings. Failure to fully participate both evenings will result in forfeit of participation fee.

Must be available:

Monday,	February 20	, 2006	6:00 -	10:00 pi	m
Monday,	February 27	, 2006	6:00 -	10:00 pt	m

All fees will be paid at the end of trading on February 27.

If you are interested in participating in this exercise, please return this sheet with the following information to Debbie Wells, 515 Ag Hall by Friday, February 17, 2006.

Name:

Major:_____

Class: Senior Junior Sophomore Freshman

Cell or local phone:

Email:

If you have questions please contact Derrell Peel at (405) 747-5882 or derrell.peel@okstate.edu.

You will be notified whether you are accepted or not by Friday, February 17, 2006.



CONSENT FORM

Project Title: Testing for Market Power in Cattle Procurement Experiments: A Nonparametric

Investigators: Dr. Chanjin Chung, PhD Dr. Clement Ward, PhD Dr. Derrell Peel, PhD Emilio Tostão, PhD candidate

Purpose: The research study seeks to develop a method for testing market power in the U.S. cattle markets. Participants in the simulation will be asked to represent packers and cattle feedlot managers, and will buy and sell cattle (represented by half-sheets of paper) just like in real cattle markets. The information sought includes bid-prices, quantity of cattle traded, the trading period in which cattle are sold, the selling feedlot team, and the buying packer team.

Procedures: Participants will be organized in teams of packer and feedlot managers. Teams are instructed to maximize profits. Packers approach feedlot and submit bids for cattle. Information required in each trading period is simulated using a computer and provided in advance to all participates. Half-sheets of paper are used to represent cattle. The participants will be asked negotiate cattle prices, and print price and the quantity sold in a trading card. Each market simulation lasts approximately four hours. Participants will be expected to participate in two simulations scheduled for February 20 and February 27.

Risks of Participation: There are no known risks associated with this project, which are greater than those ordinarily encountered in daily life. Participants must be 18 years of age or older.

Benefits: The participants will gain a better understanding of how the beef industry works particularly in its procurement market. The knowledge learned in this simulation will be extremely beneficial for students who would like to work for agribusiness firms as well as those who would like to work as a researcher in areas of agribusiness and marketing.

Confidentiality: Participation is voluntary. No personal information will be collected. The participants will be organized in groups, and the groups will be numbered. The data from the market simulation includes only the week of the trade, the price and quantity of cattle traded, the buying packer team number and the selling feedlot team number. The data will be stored in a password-protected computer. The results of the study will be reported in aggregate manner. The OSU IRB has the authority to inspect consent records and data files to

assure compliance with approved procedures.

Compensation:	Participants will be paid \$40 part more or lose part of the fee based Participants must commit to be a consecutive Monday evenings (F 6:00-10:00pm). Failure to fully pa forfeit of participation fee.	icipation fee with the opportunity to win on performance on the game. vailable for four hours each of the two ebruary 20, 2006 and February 27, 2006, articipate both evenings will result in
Contacts:	Dr. Chanjin Chung, Associate pr department of agricultural Econo For information on subjects' righ Whitehurst Hall, 405-744-1676.	ofessor, 322 Agricultural Hall, omics. Tel. 405-744-6164. ts, contact Dr. Sue Jacobs, IRB Chair, 415
Participant Rights:	Participation is absolutely volun Participants must commit to be a consecutive Monday evenings. I will result in forfeit of participat	tary. There will be no coercion. wailable for four hours each of the two Failure to fully participate both evenings fon fee.
Signatures:	I have read and fully understand voluntarily. A copy of this form	l the consent form. I sign it freely and has been given to me.
	Signature of Participant	Date

I certify that I have personally explained this document before requesting that the participant sign it.

Signature of Researcher

Date

OSU
Institutional Review Board
Approved 2117)06
Expires_2116107
had all 23

VITA

Emílio Tostão

Candidate for the Degree of

Doctor of Philosophy

Thesis: COMPETITION IN THE UNITED STATES FOOD PROCESSING INDUSTRY

Major Field: Agricultural Economics.

Education: Graduated from Francisco Manyanga Secondary School, Maputo, Mozambique, in 1989; received Bachelor of Science degree with Honors in Agronomy/Rural Engineering from *Universidade Eduardo Mondlane*, Maputo, Mozambique, 1997, and a Master of Science degree in Agricultural Economics from Oklahoma State University, 2002. Completed the requirements for the Doctor of Philosophy degree with a major in Agricultural Economics at Oklahoma State University in July, 2006.

 Experience: Undergraduate Research Assistant, Department of Rural Engineering, Universidade Eduardo Mondlane from 1993 to 1995; Research and Assistant
 Lecturer, Department of Plant Production and Protection, Agricultural Economics
 Division, Universidade Eduardo Mondlane, Maputo, Mozambique, 1997 – Present;
 Graduate Research Assistant, Department of Agricultural Economics, Oklahoma
 State University, 2003-2006. Served as a Referee to the Agricultural Economics;
 Portuguese Economic Journal

Fellowships and Awards

Award for Master of Sciences in the United States of America, Advanced Training For Leadership and Skills (ATLAS), 1999; Spillman Scholarship for top-two PhD students in agricultural economics, 2005; Leonard F. Miller Distinguished Graduate Fellowship for International Rural Development, 2006. Name: Emílio Tostão

Date of Degree: July, 2006

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: CONSOLIDATION AND MARKET POWER IN THE U.S. BEEF PROCESSING INDUSTRY

Pages in Study: 79

Candidate for the Degree of Doctor of Philosophy

Major Field: Agricultural Economics

- Scope and Methods of Study: This study contains two essays. The purpose of the first essay was to separate processors' potential market power from retailers' potential market power. Pricing rules for processors and retailers were derived considering three scenarios of imperfect competition: bilateral oligopoly assuming that processors and retailers are integrated in one sector, successive oligopoly with processor oligopsony power, and successive oligopsony with retail oligopoly power. The model was used to estimate the tradeoffs between market power and cost savings from increased concentration in the U.S. beef processing industry. The purpose of the second essay was to determine the relationship between auction and traditional new empirical industrial organization (NEIO) models of market power, and examine their relative accuracies. A theoretical model considering auctionlevel and market-level markdowns was used to show the relationship between the two models of measuring market power. Relative accuracy is measured by comparing the markdowns estimated using both models with "true" markdowns from an experimental cattle market. The traditional NEIO measure of market power was tested against the auction measure of market power using non-nested hypothesis tests.
- Findings and Conclusions: Results from the first essay showed that processor's market power effects were smaller when retailers were considered separately from processors. Processors potential efficiency gains were also small, but exceeded market power effects slightly. Therefore, further increase in concentration could lead to market power effects greater than the cost saving effects. Results showed the importance of considering processors' potential market power separately from retailers' potential market power in estimating the effects of the increased concentration in the U.S. food industry. Theoretical results from the second essay showed neither NEIO nor auction theories fully describe market power in cattle markets. Using data from an experimental cattle market it was found that both NEIO and structural auction models yield predictions of price markdowns close to actual. However, results from hypothesis tests indicated that either theory did not sufficiently explain price markdown behavior in the cattle procurement market. Theoretical results were consistent with empirical results.