MEASURING BILATERAL MARKET POWER BETWEEN PROCESSORS AND RETAILERS: AN APPLICATION TO THE U.S. BEEF INDUSTRY

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Abstract: The U.S. agricultural food processing and retailing industries have become increasingly concentrated. Therefore, numerous studies have investigated the impact of changes in market structures. This paper examines the importance of the bilateral relationship between retailers and processors in estimating market power parameters in imperfectly competitive markets. The model developed in this study allows one to estimate conjectural elasticities of input and output markets for processors and retailers separately without imposing the fixed proportions technology assumption. This study uses the primal approach to estimate the degree of market power without imposing the symmetry assumption on conjectural elasticities of input and output markets. To demonstrate the importance of considering the bilateral relationship between retailers and processors, we first generate industry data for market structures such as perfect competition, monopoly, monopsony, two-way bilateral competition, and four-way bilateral competition. The importance of using more general and flexible frameworks is demonstrated using likelihood dominance criterion (LDC), and biases in estimates of market power parameters and industry indices. We find that the model correctly estimates market power and flexible enough to consider the full range of the bilateral market power exertion. The four-way bilateral competition model is applied to the U.S. beef industry estimating conjectural elasticities from input and output markets, and corresponding market power indices. Sensitivity analysis is conducted using alternative functional forms of production function. Empirical results show that processors and retailers exercise market power in both input and output markets in the U.S. beef industry. Furthermore, estimated market power parameters and market power indices are sensitive to the choice of market structures and functional forms.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

MEASURING BILATERAL MARKET POWER BETWEEN PROCESSORS AND RETAILERS

Introduction

As agricultural food processing and retailing industries become increasingly concentrated, there have been numerous studies examining the impact of changes in market structures. Previous studies in New Empirical Industrial Organization (NEIO) focus on market structures such as horizontal concentration and vertical integration as sources of market power while maintaining hypothesis of price taking behavior on one side of the market (Appelbaum 1982; Bresnahan 1982; Lau 1982; Schroeter 1988; Atkinson and Kerkvliet 1989; Azzam 1997; Sexton 2000; Paul 2001; Chung and Tostao 2012). These studies assume that processors have oligopoly and/or oligopsony market power. However, the one-sided measure of market power may lead to inaccurate results about market power exertion because market power can potentially be exercised in both input and output markets.

A few recent studies consider bilateral imperfect competition relationship between sellers and buyers and estimate the potential market power exertion with more flexible models (Raper, Love and Shumway 2000; Chung and Tostao 2012). Raper, Love and Shumway (2000)) extend traditional NEIO methods by developing a model that allows market power exertion in both input and output markets. The model was augmented through likelihood dominance criterion (LDC) and Monte Carlo experiments to demonstrate the general model appropriately estimates parameters of market power from both sides of a market and of firms' technology. Empirical results from the U.S. leaf tobacco market show that cigarette manufacturers exercise some level of monopsony power while no monopoly power is exerted by the producers. Chung and Tostao (2012) consider a bilateral imperfect competition model between processors and retailers to measure the effect of increased concentration on industry market power and cost efficiency. They find processors tend to exercise oligopsony market power in procuring cattle but are unlikely to exercise market power on retailers. Market power effects are larger when processors and retailers are combined as single sector than when retailers are separated. Efficiency effects from the increased concentration in the U.S. beef packing industry are also slightly larger than market power effects when retailers and processors considered as one integrated sector. Although the two previous papers, Raper, Love and Shumway (2000), and Chung and Tostao (2012), recognize the importance of considering the bilateral relationship between processors and retailers, at least one side of market is limited to be competitive in these studies.

Most studies addressing market power issues in the industrial organization literature adopt a dual approach suing a firm's cost function. This approach is limited in deriving an expression for the conjectural elasticity in the factor market unless the production technology is restricted to fixed proportions between the output and input. Consequently, conjectural elasticities in the imperfect output and procured input markets turn out to be the same because quantities of output and input become identical due to the fixed proportions technology (Schroeter 1988). However, the identical market in the two markets is too restrictive because it is not an implication of the oligopoly and oligopsony theory, but is solely a result of the imposed production technology in the dual approach.

The purpose of this paper is to develop a general model that can estimate a four-way market power exertion when processors and retailers have potential market power in both buying (input) and selling (output) markets. Unlike traditional NEIO models, the general model is flexible enough to estimate a four-way bilateral market power that processors and retailers potentially exercise in both input and output markets, i.e., processors' oligopsony and oligopoly power and retailers' oligopsony and oligopoly power. To demonstrate the importance of considering the four-way bilateral relationship between retailers and processors, Monte Carlo experiments first generate industry data for market structures such as perfect competition, monopoly, monopsony, two-way bilateral competition, and four-way bilateral competition. Then, the generated data are used to estimate NEIO models with true as well as alternative market structures. The importance of using more general and flexible frameworks is demonstrated using likelihood dominance criterion (LDC[1]), and biases in estimates of market power parameters and market power indices[2]. To ensure the four-way bilateral competition, i.e., four different market power parameters in estimation, the general model is derived based on the primal approach (or production function approach) in this study. Most traditional NEIO methods use the dual approach (or the cost function approach) along with the fixed proportions assumption, which results in the same conjectural elasticities (market power parameters) of input and output markets. The primal can estimate the degree of market power without imposing the symmetry assumption on conjectural elasticities of input and output markets. Therefore, the primal approach does not require the fixed proportion assumption.

Results of Monte Carlo simulations show four-way bilateral competition model prefers to all alternative models with 100% certainty. Even if the true market structures are alternative models such as perfect competition, monopoly, and monopsony, the four-way model is chosen against the true models. The test results on market power parameter bias indicate that any erroneous modeling of market structures can lead to biased market power parameter estimates when the true market structure is the four-way bilateral model. Results also show that all alternative model specifications result in biased estimates of market power indices when the four-way model is the true market structure.

Literature Review

Many studies have used the new empirical industrial organization (NEIO) approach proposed by Appelbaum (1979, 1982) and Bresnahan (1982) to investigate the market power issue in various markets. The NEIO approach focuses on market conduct such as overall market reactions to an individual firm's change in output supply and input demand. Appelbaum (1982) considers oligopolistic market and provides an empirical framework to test various hypotheses on pricing behavior about non-competitive behavior. The study presents an empirical procedure to estimate the degree of imperfectly competitive behavior at the market level. Azzam (1997) models oligopsony only for separating the market power effects and efficiency effects associated with higher concentration in factor markets in the

U.S. beef packing industry. The study finds that the cost efficiency effect is larger than oligopsony market power effect. Paul (2001) estimates packers' market power in the beef input market and cost (utilization, scale, and scope) economies using monthly cost and revenue data from a survey of the forty-three largest U.S. beef packing plants between 1992 to 1993. Lopez, Azzam and Espana (2002) develop the oligopoly model analogous to the Azzam's oligopsony model to estimate market power and efficiency effects in oligopoly markets. Lopez, Azzam and Espana applies the oligopoly model to 32 U.S. food processing industries and finds that oligopoly power effects dominate cost efficiency effects in the meat packing industry. Schroeter (1988) adopts Appelbaum's technique for the assessment of monopolistic and monopsonistic performance. He estimates the monopoly/monopsony price distortion in the U.S. beef packing industry and finds distortions to be quite small but statistically significant. These studies tend to focus on processors alone and assume market power exercise is limited to one side of the market.

Many recent studies consider bilateral relationship between retailers and processors and measure the potential market power exertion from both sides of the market (Raper, Love and Shumway 2000; Chung and Tostao 2012). Raper, Love and Shumway (2000) develop a composite and flexible model to test market power exertion allowing the possibility that market power is exerted by firms on either or both the purchasing and selling sides of a market transaction in intermediate goods markets. Chung and Tostao (2012) follow Azzam (1997) and Lopez, Azzam and Espana (2002) theoretical work but consider bilateral imperfect competition between processors and retailers. The study estimates tradeoffs between market power and cost efficiency and examine the effects of horizontal consolidation in the U.S. beef processing industry using a bilateral imperfect competition model. One limitation of these studies is that conjectural elasticities are identical in output and input markets due to the use of the dual cost function approach.

In response to critiques on the limitations of the dual approach, a few studies use the production function approach that allows potentially different conjectural elasticities in input and output markets without imposing the assumption of fixed proportion technology (Azzam and Pagoulatos 1990; Chang and Tremblay 1991; Mei and Sun 2008). Azzam and Pagoulatos (1990) estimate conjectural elasticities for input and output markets of the U.S. meat packing industry and find that the industry is imperfectly competitive in both markets. Chang and Tremblay (1991) present an analytical derivation of indices (similar to Lerner Index) that can reflect degrees of market power in input and output markets. The study first develops a firm-level index and then extends it to the market-level index. The market level index is a market share weighted index from the firm-level index. Mei and Sun (2008) also use the production function approach to estimate oligopoly and oligopsony market power in the U.S. paper industry. The study finds the presence of market power in both paper products and pulpwood markets for the past several decades. Although recent studies, e.g., Raper, Love and Shumway (2000) and Chung and Tostao (2012), examine the bilateral relationship between retailers' and processors' market power by employing more flexible models than previous studies, the models developed in these studies are yet not flexible enough to consider the full range of the four-way bilateral market power relationship. These models do not allow one to estimate the potential market power of retailers and processors separately in each of input and output markets.

Our study develops by far the most flexible model that considers the full range of the bilateral market power relationship between retailers and processors and investigates the importance of this consideration in estimating the degree of market power. We draw on Raper, Love and Shumway (2000) and Chung and Tostao (2012), but our study differs from these studies at least in two areas. First, our study begins deriving a conceptual model from separates processors' and retailers' profit maximization problems and combine first order condition of these maximization problems using the bilateral relationship. The model includes four conjectural elasticities that represent retailers' and processors' market power in input and output markets, respectively. Therefore, unlike previous studies, it allows one to estimate the full range of the bilateral market power relationship between retailers and processors. Second, our model is based on the production function approach so that it does not require the symmetry assumption on conjectural elasticities between input and output markets. Most previous studies are based on the dual approach which requires identical conjectural elasticities of factor and output markets under the fixed proportions technology assumption.

Theoretical Framework

In general, there are two approaches in developing a theoretical framework of conjectural elasticity in the NEIO literature. One is the primal approach which employs a production function in the specification of a firm's profit maximization problem. In optimum when profit is maximized, the input demands can be derived by the Hotelling's lemma. The other is the dual approach which uses a cost function in specifying a firm's profit maximization problem. In optimum when cost is minimized, the input demand equations are obtained by the Shephard's lemma. In both cases, conjectural elasticity can be identified and the system of equations for output production and input demands in equilibrium can be jointly estimated.

However, one limitation of the dual cost function approach is that the derivation of conjectural elasticity in input market is not straightforward unless the production technology is restricted to fixed proportions (Azzam and pagoulatos 1990). In the cost function approach, the market output and input are represented by an identical variable in the profit function with appropriately chosen dimensions to derive the conjectural elasticity in the input market (Schroeter 1988)[3]. As a result, identical conjectural elasticities are derived by factor and output markets under the dual cost function framework. To avoid this limitation, we use the production function approach that allows potentially different degree of market power in input and output markets.

Consider a processor firm that uses a vector of inputs, *z*, with associated prices, *w*, to produce a single output, y^p, for sale as an input to retailer firms. The j^{th} firm's production function can be stated as:

(1) $$y_j^p = f(y_j^f, z_{uj}),$$

where y_j^p is the output produced, y_j^f is the farm input, z_{uj} (indexed *u=1,…, U*) represents non-farm inputs such as labor, capital, and materials that are purchased from a competitive market. Furthermore, assume each firm exercises some degree of market power in purchasing the farm input, y_j^f and in selling its output, y_j^p. The inverse market demand function is given by:

(2) $$P^p = f(Y^P),$$

where P^p and $Y^p = \sum_{j=1}^{N} y_j^p$ are the price per unit of the processed output and the total industry output. The inverse market supply function for the specific factor input is given by:

(3) $$P^f = h(Y^f),$$

where P^f and $Y^f = \sum_{j=1}^{N} y_j^f$ are market farm input price and total industry input. Denoting the price of non-farm inputs by $w_1, \ldots, w_u$ and assuming each firm is a profit maximizing. Thus, the profit maximization problem for the representative j^{th} processors firm can be stated as:

$$\Pi_j^p = P^p(Y^p)y_j^p - P^f(Y^f)y_j^f - \sum_{u=1}^{3} w_u z_{uj}, \tag{4}$$

for $j=1, 2, \ldots, N$, subject to (2) and (3). The first-order necessary conditions corresponding to this maximization problem are given by (see Appendix A for detailed derivation):

$$P^p\left(1+\frac{\xi_j}{\varepsilon_d^p}\right)f_{y_j^f} - P^f\left(1+\frac{\theta_j}{\varepsilon_s^f}\right) = 0, \tag{5}$$

$$P^p\left(1+\frac{\xi_j}{\varepsilon_d^p}\right)f_{Z_{uj}} - w_u = 0, \tag{6}$$

or

$$\frac{P^f}{P^p} = \left(1+\frac{\xi_j}{\varepsilon_d^p}\right)f_{y_j^f} - \frac{P^f}{P^p}\left(1+\frac{\theta_j}{\varepsilon_s^f}\right), \tag{7}$$

$$\frac{w_u}{P^p} = \left(1+\frac{\xi_j}{\varepsilon_d^p}\right)f_{Z_{uj}}, \qquad j = 1, \ldots, N \text{ and } u = 1, \ldots, U, \tag{8}$$

where $\xi_j = \frac{\partial Y^p}{\partial y_j^p}\frac{y_j^p}{Y^p}$ is the j^{th} firm's conjectural elasticity in the output market;

$\theta_j = \frac{\partial Y^f}{\partial y_j^f}\frac{y_j^f}{Y^f}$ is the j^{th} firm's conjectural elasticity in farm input market;

$\varepsilon_d^p = -\frac{\partial Y^p}{\partial P^p}\frac{P^p}{Y^p}$ is the price elasticity of output demand;

$\varepsilon_s^f = \frac{\partial Y^f}{\partial P^f}\frac{P^f}{Y^f}$ is the price elasticity of the farm input supply;

$f_{y_j^f} = \frac{\partial y_j^p}{\partial y_j^f}$ is the marginal product of the farm input used by firm j;

and $f_{z_{uj}} = \frac{\partial y_j^p}{\partial z_{uj}}$ is the marginal product of the u^{th} input used by firm j.

Now, consider a retailer firm that uses a vector of inputs, *x*, with associated prices, *v*, to produce a single output, y^r, for sale to consumers. Let the firm i^{th} production function be:

(9) $$y_i^r = f\left(y_i^p, x_{ki}\right),$$

where y_i^r is retail output, y_i^p is the processed input, x_{ki} (indexed *k=1, …, K*) represent other inputs like as labor, capital, and materials that is purchased from a competitive market. The inverse market demand function is given by:

(10) $$P^r = f(Y^r),$$

where $Y^r = \sum_{i=1}^{N} y_i^r$ is the total industry output, and P^r is the price per unit of the retail output. The inverse market supply of the specific factor is given by:

(11) $$P^p = g(Y^p),$$

where P^p and $Y^p = \sum_{i=1}^{N} y_i^p$ are market processed input price and total industry input from the processor. Denoting the price of non-farm inputs by $v_1, \dots, v_k$, and assuming each firm is a profit maximize. The profit maximization problem for the i^{th} retailer firm can be stated as:

(12) $$\Pi_i^r = P^r(Y^r)y_i^r - P^p(Y^p)y_i^p - \sum_{k=1}^{3} v_k x_{ki}.$$

The first-order necessary conditions corresponding to this profit maximization problem are given by (see Appendix A for the detailed derivation):

(13) $$P^r\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{y_i^p} - P^p\left(1+\frac{\delta_i}{\varepsilon_s^p}\right)=0,$$

(14) $$P^r\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{x_{ki}} - v_k = 0,$$

or

(15) $$\frac{P^p}{P^r}=\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{y_i^p} \; - \frac{P^p}{P^r}\left(1+\frac{\delta_i}{\varepsilon_s^p}\right),$$

(16) $$\frac{v_k}{P^r}=\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{x_{ki}}, \qquad i=1,\dots,N \text{ and } k=1,\dots,K,$$

where $\phi_i=\frac{\partial Y^r}{\partial y_i^r}\frac{y_i^r}{Y^r}$ is the i^{th} retailer firm's conjectural elasticity in output market;

$\delta_i=\frac{\partial Y^p}{\partial y_i^p}\frac{y_i^p}{Y^p}$ is the i^{th} retailer firm's conjectural elasticity in input market;

$\varepsilon_d^r=-\frac{\partial Y^r}{\partial P^r}\frac{P^r}{Y^r}$ is the price elasticity of output demand;

$\varepsilon_s^p=\frac{\partial Y^p}{\partial P^p}\frac{P^p}{Y^p}$ is the price elasticity of the processed input supply;

$f_{y_i^p}=\frac{\partial y_i^r}{\partial y_i^p}$ is the marginal product of the processed input used by firm i;

and $f_{x_{ki}}=\frac{\partial y_i^r}{\partial x_{ki}}$ is the marginal product of the k^{th} input used by firm i.

The conjectural elasticities ξ_j, θ_j, ϕ_i, and δ_i provide useful benchmarks in investigating competitive behavior and allow one to carry out various tests about market structure (Azzam and Pagoulatos 1990). The parameter $\xi_j \in [0,1]$ and $\delta_i \in [0,1]$ measure the departures from competition in selling output. $\theta_j \in [0,1]$ and $\phi_i \in [0,1]$ measure the departures from competition in buying an input. Assuming positive marginal products, if both ξ_j and θ_j are equal to 0 in equations (7) and (8), we have the perfectly competitive case where each firm equates the value of marginal product of each input to its marginal cost in the processing sector. In the extreme case where both ξ_j and θ_j are equal to 1, we obtain the monopoly and monopsony case. Other combinations of market structures can be identified with the values that denote various degrees of oligopoly/oligopsony power with higher values of both ξ_j and θ_j indicating greater departures from competitive behavior.

The parameters ϕ_i and δ_i are playing a similar role in the retailing sector. If both ϕ_i and δ_i are equal to 0 in equations (15) and (16), we have the perfectly competitive case for retailing sector. When ϕ_i and δ_i are equal to 1, we obtain the monopoly and monopsony case. Other values denote various degrees of oligopoly and oligopsony power with higher values of both ϕ_i and δ_i.

The market power index[4] is the difference between the value of the marginal product and the input price all divided by the value of the marginal product. This approach is similar to that developed by Lerner (1932), who defined the index of monopoly price distortions as the difference between the output price and marginal cost divided by the price. The market power index for processor firm *j* is derived such as:

(17) $$M_j^p = \left[P^P \left(MP_{y_j^f}\right) - P^f\right] / \left[P^P \left(MP_{y_j^f}\right)\right].$$

Rearranging this equation with market power parameters becomes:

(18) $$M_j^p = \left(\frac{\theta_j}{\varepsilon_s^f} + \frac{\xi_j}{\varepsilon_d^p}\right) / \left(1 + \frac{\theta_j}{\varepsilon_s^f}\right).$$

Because the value of the marginal product at the processor level is greater than or equal to P^f for competitive or imperfectly competitive market, the value of M_j^p should range between 0 and 1. When the factor is paid equal to the value of its marginal product, $P^P\left(MP_{y_j^f}\right) = P^f$, then $M_j^p = 0$ and the industry is efficient (competitive) in both input and output markets. As the difference in the value of the marginal product and the factor price increases, M_j^p approaches 1. Thus, greater inefficiency is implied by the higher values of M_j^p. In the processor sector, $\frac{\xi_j}{\varepsilon_d^p}$ reflects the non-competitive performance in the output market and reduces to the well-known Lerner index of $\frac{1}{\varepsilon_d^p}$ for the case of the pure monopolist. $\frac{\theta_j}{\varepsilon_s^f}$ reflects the non-competitive performance in the input market and reduces to $\frac{1}{\varepsilon_s^f}$ for the pure monopsonist. An index for retailers is obtained by similar procedure. The index for retailers plays a similar role and is obtained in an analogous manner for firm level. The index for retailer firm *i* is derived such as:

(19) $$M_i^r = \left(\frac{\delta_i}{\varepsilon_s^p} + \frac{\phi_i}{\varepsilon_d^r}\right) / \left(1 + \frac{\delta_i}{\varepsilon_s^p}\right).$$

In practice, the absence of firm-level data generally requires an additional assumption to make the preceding analysis relevant to the behavior of the industry as whole. We assume that at equilibrium, conjectural elasticities in processing and retail sectors are invariant across firms, i.e., $\xi_1 = \xi_2 = \cdots = \Xi$, and $\theta_1 = \theta_2 = \cdots = \Theta$. The conjectural elasticities in the retailing sector, also, are invariant across the firm $\phi_1 = \phi_2 = \cdots = \Phi$ and $\delta_1 = \delta_2 = \cdots = \Delta$. Then, the aggregate analogue of the optimality condition in processing and retailing sector can be written as:

(20) $$\frac{P^f}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Y^f} - \frac{P^f}{P^p}\frac{\Theta}{\varepsilon_s^f},$$

(21) $$\frac{w_u}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_u},$$

(22) $$\frac{P^p}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{Y^p} - \frac{P^p}{P^r}\frac{\Delta}{\varepsilon_s^p},$$

(23) $$\frac{v_k}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{X_k}.$$

Therefore, the industry-level market power index for processor and retailer can be stated as:

(24) $$M^{P^*} = \left(\frac{\Theta}{\varepsilon_s^f} + \frac{\Xi}{\varepsilon_d^p}\right) / \left(1 + \frac{\Theta}{\varepsilon_s^f}\right),$$

(25) $$M^{R^*} = \left(\frac{\Delta}{\varepsilon_s^p} + \frac{\Phi}{\varepsilon_d^r}\right) / \left(1 + \frac{\Delta}{\varepsilon_s^p}\right).$$

Empirical Model

Monte Carlo experiments and empirical estimation of NEIO models require a specific functional form for the production function in equations (4) and (12). It is desirable that the functional form does not impose severe *a priori* constraints on the production characteristics of the industry. One flexible functional form that has been generally adopted in many NEIO models is the generalized Leontief production function (Diwert 1971)[5]. The generalized Leontief production functions for the processor that uses a vector of inputs, *Z*, to produce a single output, Y^p is:

(26) $$Y^p = \alpha_{11}Y^f + \alpha_{22}Z_l + \alpha_{33}Z_c + \alpha_{44}Z_m + 2\alpha_{12}(Y^f Z_l)^{\frac{1}{2}} + \alpha_{13}(Y^f Z_c)^{\frac{1}{2}}$$
$$+2\,\alpha_{14}(Y^f Z_m)^{\frac{1}{2}} + 2\alpha_{23}(Z_l Z_c)^{\frac{1}{2}} + 2\alpha_{24}(Z_l Z_m)^{\frac{1}{2}} + 2\alpha_{34}(Z_c Z_m)^{\frac{1}{2}}.$$

We assume that in addition to the farm input (Y^f), there are three competitively priced inputs utilized by the processor: labor (Z_l), capital (Z_c), and material (Z_m). From equation (26), we can get the marginal product of input for processors (see Appendix B for detailed derivation). Substituting the marginal product of input into Equation (20) and (21), and rearranging, leads:

(27) $$S_1^p = \frac{\left(1+\frac{\Xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\Theta}{\varepsilon_s^f}\right)}\left(\alpha_{11} + \alpha_{12}\left(\frac{Z_l}{Yf}\right)^{\frac{1}{2}} + \alpha_{13}\left(\frac{Z_c}{Yf}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{Z_m}{Yf}\right)^{\frac{1}{2}}\right),$$

(28) $$S_u^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_u},$$

where $S_u^p = \frac{w_u}{P^p}$ (for $u = 1, 2, 3$) is the share equation for the u^{th} input for the processors. Ξ and Θ are parameter index of monopolistic and monopsonistic market power exertion which is bounded between 0 and 1.

Now, consider the retailer firm that produces a single output, Y^r, using the intermediate goods produced by the processor firm as its primary input, Y^p, and a vector of other inputs, *X*, is written:

(29) $$Y^r = \beta_{11}Y^p + \beta_{22}X_1 + \beta_{33}X_2 + \beta_{44}X_3 + 2\beta_{12}(Y^pX_1)^{\frac{1}{2}} + 2\beta_{13}(Y^pX_2)^{\frac{1}{2}}$$

$$+2\beta_{14}(Y^pX_3)^{\frac{1}{2}} + 2\beta_{23}(X_1X_2)^{\frac{1}{2}} + 2\beta_{24}(X_1X_3)^{\frac{1}{2}} + 2\beta_{34}(X_2X_3)^{\frac{1}{2}}.$$

Similarly, retailer's marginal product and share equations are obtained as:

(30) $$S_1^r = \frac{\left(1+\frac{\Phi}{\varepsilon_d^r}\right)}{\left(1+\frac{\Delta}{\varepsilon_s^p}\right)}\left(\beta_{11} + \beta_{12}\left(\frac{X_l}{Y^p}\right)^{\frac{1}{2}} + \beta_{13}\left(\frac{X_c}{Y^p}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{X_m}{Y^p}\right)^{\frac{1}{2}}\right),$$

(31) $$S_k^r = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{x_k},$$

where $S_k^r = \frac{v_k}{P^r}$ (for $k = 1, 2, 3$) is the share equations for the k^{th} input for retailers.

Equations (26) to (31) constitute a system of ten equations in total. For empirical estimation and Monte Carlo simulation, the production function and the share equations are assumed to be stochastic due to technical and optimization errors. The errors are assumed to be additive multivariate normal distributed and added to each structural equation.

Data

The data used in the Monte Carlo simulations are monthly data series for the U.S. beef industry ranging from years 1980 to 2011. The data are compiled from the National Agricultural Statistic Service (NASS), Grain Inspection, Packers and Stockyards Administration (GIPSA), and the Economic Research Service (ERS) of the United State Department of Agriculture (USDA).

Total beef production represented by steer and heifer slaughter quantities is compiled from Livestock Slaughter Annual Summary of National Agricultural Statistics Service (NASS), United States Department of Agriculture (USDA). Total cattle input supply is represented by the cattle slaughter quantity in total live weight (NASS, USDA), and prices of labor, capital, and material inputs for the U.S. beef packing industry (NAICS code: 3116) are obtained from the Industry Productivity and Costs Database of Bureau of Labor Statistics (BLS), United States Department of Labor (USDL). The Herfindahl-Hirschman 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 (1996-2011), Grain Inspection, Packers and Stockyards Administration (GIPSA), USDA. Prices series of wholesale and cattle is provided by ERS, USDA.

Retail output is represented by the total US commercial beef production obtained from *red meat year book* (ERS, USAD). Prices of labor, capital, and material inputs for food retailers are obtained from the *Major Sector Multifactor Productivity Index Database* (BLS, USDL). Retail Herfindhal-Hirschman Index (HHI) data are available only for years 1992, 1997, 2002, and 2007 which is estimated using sales data of the 50 largest grocery stores in the United States. Given the paucity of data, the Herfindhal-Hirschman Index data for the remaining years are estimated in time series regression. The retail sales data are obtained from several issues of the *Progressive Grocer Magazine* (Progressive Grocer, 1970-2002) and the U.S. Census Bureau. The retail price of beef is compiled from ERS, USDA.

For the beef supply equation and the processed beef supply equation, the productivity of labor, capital and the food processing materials are obtained from the *Major Sector Multifactor Productivity Index Database* (BLS, USDL). The productivity of labor, capital and materials for the U.S. animal slaughtering and processing industries are obtained from the *Industry Productivity and Cost Database* (BLS, USDL). The definitions and descriptive statistics of these variables are presented in Table I-1.

Monte Carlo Experiments

To demonstrate the importance of the bilateral relationship between retailers and processors in estimating market power parameters, we first simulate industry data under alternative industry structures using Monte Carlo techniques and then estimate market power parameters for each simulated structure. To do so, we use known or 'true' market power parameter for each simulated industry data. The true market power parameters are compared with estimated parameters obtained from various market power estimation procedures. We simulate the share equations from (26) to (31) for six 'true' market structures: perfect competition, monopoly, monopsony, combined two-way bilateral imperfect competition, separated two-way bilateral imperfect competition, and four-way bilateral imperfect competition. Combined two-way bilateral imperfect competition is similar to the models considered in previous study (Schroeter 1988; Chung and Tostao 2012). In this case, retailers and processors are integrated in a single 'processing/retailing' sector, which competes imperfectly in procuring farm inputs from a perfectly competitive farm sector and in selling processed product to consumers. Separated two-way bilateral imperfect competition is derived from the models used in previous study (Raper, Love and Shumway 2000). In this case, processors are allowed to have oligopoly power in selling processed product to retailers. Retailers are allowed to have oligopsony power in procuring processed output from processors. Four-way bilateral imperfect competition nests the Raper, Love and Shumway (2000) and Chung and Tostao (2012). This model allows having processors' oligopsony and oligopoly power and retailers' oligopsony and oligopoly power.

Firm level data are a rarity in real world application. Since we seek to closely imitate data limitations faced by researchers, industry data are generated for each market structure. One thousand data sets with the three hundred and eighty observations are generated for each market structure. Data generating procedure is as follows. First, derive a conceptual model from separates processors' and retailers' profit maximization problems. Second, assume perfectly competitive market in both processors and retailers and estimate equations from (26) to (31) simultaneously, and then we can get parameters used as starting values and the variance-covariance matrix. Third, we construct variance-covariance matrix used to simulate random error using Cholesky decomposition method. Fourth, additive multivariate normal errors appended to each structural equation for stochastic simulation of endogenous variables. Finally, generate industry data for each market structure using known or true market power parameters. The design matrix for the parameters and the variance-covariance matrix used to simulate random error term are given in Appendix C. The exogenous and endogenous variables used in simulating market data are presented in Table I-1. Additive multivariate normal errors are assumed to each structural equation for stochastic simulation of endogenous variables. Appendix D contains functional form for simulated and estimated market structures.

Competitive market data are simulated by jointly aggregate versions of share equations for both the processor and retailer firm and production function for processors and retailers. These equations are based on equations (4) and (12) and solved for $S_1^p, S_m^p, S_1^r, S_k^r, Y^p$, and Y^r using processors and retailers production functions given in equations (26) and (29). All conjectural elasticities are set to be zero where each firm equates the marginal product of each input to its real price. The monopoly solution is obtained assuming the processor firm maximizes profit by exercising monopoly power while the retailer firm behaves passively. In this case, the conjectural elasticity, Ξ, is equal to 1, but the conjectural elasticities, $\Theta, \Phi,$ and Δ, are equal to 0. The monopsony solution is obtained similarly assuming the retail firm maximizes profit by exercising monopsony power subject to the processor firm competitively determining intermediate good supply. The conjectural elasticity, Δ, is equal to 1 and the others are equal to 0.

In the two-way bilateral imperfect competition case, we consider two cases. First, the combined (or integrated processing-retailing) two-way bilateral imperfect competition model is considered. In this case, an integrated processing-retailing firm competes imperfectly in procuring farm inputs and in selling processed products to consumers. This type of bilateral imperfect competition model is similar to the models considered in previous studies such as Schroeter (1988) and Chung and Tostao (2012). For this case, we set both conjectural elasticities, Φ and Θ, are equal to 0.5, respectively. Second, the separated two way bilateral imperfect competition is considered. In this case, we consider two separate firms: processor and retailer, where processor has only some degree of oligopoly power in selling processed products to retailers while retailer has only some degree of oligopsony power in buying processed product from processors. Conjectural elasticities, Ξ and Δ, are set at 0.5, respectively for this case. Four-way bilateral imperfect competition allows both processor and retailer to have oligopoly power in selling output and to have oligopsony power in procuring input. In this case, we set all conjectural elasticities to be 0.25. In addition, absolute values of demand elasticities, ε_d^p and ε_d^r are given as 0.45 and supply elasticities, ε_s^f and ε_s^p are given as 0.15[6].

Results of Estimated Market Structures and Hypothesis Tests

Each econometric specification is estimated as a system of ten simultaneous equations ($S_1^p,\ S_m^p,\ S_1^r,\ S_k^r, Y^p,$ and Y^r) with additive multivariate normal errors using full information maximum likelihood estimation procedure. The method of instrumental variables is used because some variables in equations (for example, output and factors) are endogenous. The instrumental variables included in the estimation are prices of the three inputs in processing and retailing sectors, Herfindahl-Hirschman indices for the US beef processing and retailing industries, per capita disposable income, and time trend.

Table I-2 shows mean values and standard deviations for estimated market power parameters in alternative models for each simulated (true) market structure. When the true market structure is four-way bilateral imperfect competition, the misspecified alternative econometric specifications estimate the market power parameter to be significantly different from its true value. The four-way bilateral imperfect competition model performs equally as the perfect competition, monopoly, monopsony, and separated two-way bilateral imperfect competition specifications in estimating market power parameters. This is a remarkable result because the four-way bilateral imperfect competition model does not require *a priori* restriction that limits market power exercise in one side of market at least and is able to estimate correct market power parameters from true market structures.

Three statistical tests, model selection test using LDC, test for biases in estimated market power parameters, and test for biases in estimated market power indices, are used to demonstrate the importance of using the four-way bilateral model in measuring the degree of market power. Market structures considered in this study include perfect competition, monopoly, monopsony, two-way bilateral competition, and four-way bilateral competition. First, the LDC test use the likelihood ratio test that requires maximum likelihood estimates of the two hypotheses, H_o(true market structure) and H_a(alternative market structure). Following Pollack and Wales (1991),

H_o is preferred to H_a if

(32) $$L_a - L_o < [C(n_a + 1) - C(n_o + 1)]/2,$$

H_a is preferred to H_o if

(33) $$L_a - L_o > [C(n_a - n_o + 1) - C(1)]/2,$$

where L_o and L_a denote the log likelihoods corresponding to each hypothesis and $C(v)$ denote the critical values of the chi-square distribution with v degrees of freedom at 5% significance level. n_o and n_a denote the number of independent parameters in each null and alternative hypothesis.

LDC cannot define between H_o and H_a if

(34) $$\frac{[C(n_a-n_o+1)-C(1)]}{2} \geq L_a - L_o \geq \frac{[C(n_a+1)-C(n_o+1)]}{2}.$$

Since n_o and n_a are known and L_o and L_a are obtained from model estimations, the LDC test is easily implemented. The appropriate upper and lower critical values are computed for each pairwise comparison at the 5% significance level.

Results of model selection tests are reported in Table I-3. Pairwise comparisons between null (true) and each alternative econometric specification shows that the four-way bilateral imperfect competition model should be used to estimate the four-way market power parameters for retailers' and processors' potential market power in both input and output markets. When the true market structure is the four-way bilateral imperfect competition, the LDC rejects the misspecified alternative econometric specifications while favoring the simulated market structure 100% of the time. Even if the true market structure are perfect competition, Monopoly, are Monopsony, LDCs clearly choose the four-way bilateral imperfect competition over the true market structures 117 times, 95 times, and 171 times, respectively. If we include undefined cases between true and alternative models, the four-way model is chosen against the true perfect competition, monopoly, and monopsony models 28.8%, 41.1%, and 39.7% of the time, respectively. When two-way combined model is true, LDC chooses the four-way bilateral imperfect competition over the true model 89 times.

When two-way separated model is true, the four-way model is favored 135 times while 364 cases are undefined.

Results from Table I-3 clearly show the importance of using the four-way model to estimate the bilateral market power relationship between retailers and processors and that the four-way model is flexible enough to represent other alternative market structures. The second method to demonstrate the importance of modeling four-way bilateral imperfect competition in NEIO framework is to test biases of estimated market power parameters. The true market power parameters used in generating market level data are compared to those estimated from alternative market structures. The null hypothesis is that there is no bias between the market power parameters of the simulated market structure and each alternative econometric specification, and standard t-tests are carried out at the 5% significance level.

T-test results on market power parameter bias are presented in Table I-4. When the four-way bilateral imperfect competition is the true structure, market power parameter biases from alternative market structures such as monopoly, monopsony, and two-way bilateral imperfect competition models are all statistically different from zero. Therefore, the results indicate that any erroneous modeling of market structures can lead to biased market power parameter estimates when the true market structure is the four-way bilateral relationship. Even if true market structures are perfect competition monopoly, monopsony, and two-way bilateral imperfect competition, the flexible four-way model is able to estimate correct market power parameters with zero biases except monopoly and combined two-way bilateral imperfect competition. The t-test results on market power parameter estimates show that the four-way bilateral imperfect competition model has a clear advantage in estimating market power parameters. In other words, the four-way bilateral imperfect competition model could be more flexible than the two-way bilateral imperfect competition model and one direction models. Overall, the results are consistent with the LDC results from Table I-3.

Finally, market power indices that reflect overall degree of industry market power from both input and output markets are estimated and tested if they statistically differ from the true indices. Again, the true indices are computed from the parameter values used in generating data. The biases between true and estimated values are non-parametrically tested using 95% confidence intervals without assigning any particular probability distributions. Table I-5 presents confidence intervals for market power index bias between true and alternative models. With the four-way model specification as the true market structure, all alternative model specifications result in biased estimates of market power indices. The result is consistent with results from LDC and market power parameter bias tests in table I-3 and I-4, respectively. Even if the true market structure is perfectly competitive, monopoly, monopsony, or two-way bilateral relationship, the four-way model estimates corresponding market power indices correctly in some cases. For example, when true market structure is perfectly competitive, the four-way model results in no biased estimates compared to the true parameters. When monopoly is the true market structure, the four-way model correctly estimates for processors' index while the four-way model correctly estimates retailers' index correctly when the true market structure is monopsony. When the simulated market structure is the separated two-way bilateral imperfect competition, the four-way model correctly estimates processors' and retailers' market power indices in each processors' and retailers' sector.

Conclusions

Many recent studies have estimated potential market power effects from increased concentration for various industries. However, these studies assess market power effects of an integrated processor-retailer industry or bilateral imperfect competition markets while imposing restriction in the direction of market power exertion.

This paper considers bilateral imperfect competition between processors and retailers and demonstrates the importance of modeling processors' and retailers' oligopoly and oligopsony power in both input and output market. Our study estimates conjectural elasticities of input and output markets for processors and retailers separately employing the primal production function approach. To validate our bilateral market power exertion between processors and retailers, we first generate market data under various market structures using Monte Carlo techniques and then estimate market power parameters for each simulated structure. The importance of using more general and flexible frameworks is demonstrated using likelihood dominance criterion (LDC), and biases in estimates of market power parameters and market power indices

Results suggest that the general framework developed in this study does not make *a priori* assumptions regarding the direction of market power exertion and is also flexible enough to allow the full range of market structures. Results of Monte Carlo simulations clearly showed the importance of using the four-way model to estimate the bilateral market power relationship between retailers and processors and that the four-way model is flexible enough to represent other alternative market structures. When the true market structure is the four-way bilateral imperfect competition, the LDC model selection test rejects the misspecified alternative econometric specifications while favoring the simulated market structure 100% of the time. Even if the true market structure is one of alternative structures, the test chooses the four-way bilateral imperfect competition over the true market structures in many cases.

Results from bias tests on market power parameter estimates indicate that any erroneous modeling of market structures can lead to biased market power parameter estimates when the true market structure is the four-way bilateral relationship. Even if true market structures are perfect competition monopoly, monopsony, and two-way bilateral imperfect competition, the flexible four-way model is able to estimate correct market power parameters with zero biases in most cases.

Finally, results of bias tests with market power indices were consistent with those from LDC and market power parameter bias tests. When the true market structure is the four-way bilateral-imperfect competitive, all alternative model specifications result in biased estimates of market power indices. Even if the true market structure is perfectly competitive, monopoly, monopsony, or two-way bilateral relationship, the four-way model estimates corresponding market power indices correctly in some cases.

Footnotes

1. Pollak and Wales (1991) propose a new asymptotic criterion for model selection. Their approach to model selection is based on two new concepts: dominance ordering and the likelihood dominance criterion (LDC). The LDC generalizes the dominance ordering by considering a set of admissible composite parametric sizes rather than a single composite parametric size. See Pollak and Wales (1991) and Raper *et al.*, (2000).
2. This index allows for non-competitive behavior in both factor and output markets. Chang and Tremblay (1991) refer as an oligopsony/oligopoly index.
3. Although Schroeter developed a measure of monopsony power, it applies only to the special case where the production technology is characterized by fixed proportions between the quantity of output and the quantity of the demand input.
4. This approach is similar to the Lerner Index developed by Lerner (1932), who defined the index of monopoly price distortions as the difference between the output price and marginal cost divided by the price. The market power index for firm level is:

   The share equation (7),

   $$\frac{P^f}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - \frac{P^f}{P^p}\left(1 + \frac{\theta_j}{\varepsilon_s^f}\right),$$

   Divide the share equation by $f_{y_j^f}$ gives:

$$\frac{P^f}{P^p f_{yf}} = \left(1 + \frac{\xi}{\varepsilon_d^p}\right) - \frac{P^f}{P^p f_{yf}} \frac{\theta}{\varepsilon_s^f} \Rightarrow \frac{P^f}{P^p f_{yf}} = \frac{\left(1+\frac{\xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\theta}{\varepsilon_s^f}\right)}.$$

Multiplying both sides by -1 and adding $\frac{P^p f_{yf}}{P^p f_{yf}}$ yields:

$$\frac{P^p f_{yf}}{P^p f_{yf}} - \frac{P^f}{P^p f_{yf}} = 1 - \frac{\left(1+\frac{\xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\theta}{\varepsilon_s^f}\right)} \Rightarrow \frac{P^p f_{yf} - P^f}{P^p f_{yf}} = 1 - \frac{\left(1+\frac{\xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\theta}{\varepsilon_s^f}\right)}.$$

Simplifying and rearranging results in:

$$\frac{P^p f_{yf} - P^f}{P^p f_{yf}} = \frac{\left(\frac{\theta}{\varepsilon_s^f} - \frac{\xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\theta}{\varepsilon_s^f}\right)}$$

In previous studies, Lerner index for the monopoly is defined as;

$L^p = \frac{P-MC}{P} = -\frac{\xi}{\varepsilon_d^p}$, where ε_d^p is the price elasticity of demand.

In this study, the market power index for the monopolist firm *j* is defined as;

$$I_j^p = \frac{P^p f_{yf} - P^f}{P^p f_{yf}} = -\frac{\xi}{\varepsilon_d^p}$$

5. The generalized Leontief production function is one of the most flexible functional forms, permitting the partial elasticities of substitution between inputs to vary.
6. The demand elasticities are obtained from Brester and Wohlgenana (1993). The supply elasticities are from USDA, ERS. In this paper, each demand and supply elasticities is assumed to be same for processors and retailers.

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Table I-1. Descriptive Statistics of Variables Used in the Empirical Estimation (1980.1-2011.12, N=384)

Variable	Symbol	Mean	SD	Minimum	Maximum
Herfindahl Hirschman index for steer and heifer slaughter	H^p	0.1646	0.0475	0.0561	0.2268
Herfindahl Hirschman index for grocery retailers	H^r	0.0397	0.0247	0.0081	0.0763
Commercial beef production (billion lbs.)	Y^r	2.0489	0.1825	1.653	2.512
Wholesale beef production (billion lbs.)	Y^p	2.7377	0.2218	2.2275	4.1485
Cattle slaughter weight (billion lbs.)	Y^f	3.4221	0.2772	2.7843	4.1485
Retail price of beef ($/cwt)	P^r	120.28	15.579	92.23	156.41
Wholesale value of beef ($/cwt)	P^p	80.058	3.248	73.926	92.314
Farm value of beef	P^f	69.280	1.299	62.843	74.899
Labor productivity for food and other industry (2005=100)	Y^r/Z_L	94.71	8.24	80.78	109.11
Capital productivity (2005=100)	Y^r/Z_C	102.78	2.909	96.54	107.48
Material productivity (2005=100)	Y^r/Z_M	86.04	13.43	67.10	106.19
Price of labor (2005=100)	V_L	109.07	4.361	100.00	119.73
Price of capital (2005=100)	V_C	125.91	13.24	97.06	148.91
Price of material (2005=100)	V_M	93.00	3.737	85.52	100.63
Labor productivity for animal slaughtering and processing (2005=100)	Y^p/X_L	97.97	8.659	83.57	112.85
Capital productivity (2005=100)	Y^p/X_C	101.98	1.974	97.43	105.61
Material productivity (2005=100)	Y^p/X_M	91.81	9.077	78.18	114.15
Price of labor (2005=100)	W_L	91.22	27.75	44.26	135.71
Price of capital (2005=100)	W_C	84.71	30.43	45.92	173.95
Price of material (2005=100)	W_M	102.97	22.222	70.50	158.22

Table I-2. Mean Values of Estimated Market Power Parameters from True and Alternative Models

Simulated (true) market structure			Monopoly	Monopsony	Two-way bilateral imperfect competition: Combined		Two-way bilateral imperfect competition: Separated		Four-way bilateral imperfect competition			
			Ξ	Δ	Φ	Θ	Ξ	Δ	Ξ	Θ	Φ	Δ
Perfect competition			0.0000* (0.0024)	-0.0000* (0.0006)	-0. 3219 (0.0423)	-0. 0877 (0.0211)	0.0000* (0.0025)	-0.0000* (0.0006)	0.0007* (0.0287)	0.0002* (0.0094)	0.0244* (0.1345)	0.0082* (0.0455)
Monopoly		Ξ	1.0000* (0.0027)	-0.0089 (0.0041)	-0.3219 (0.0423)	-0.0877 (0.0211)	1.0000* (0.0028)	-0.0000* (0.0006)	0.9699* (0.1849)	-1.52E72 (3.27E73)	0.099* (1.8076)	-2.88E46 (8.69E47)
Monopsony		Δ	-0.0003* (0.0086)	1.0003* (0.0313)	-0.3219 (0.0423)	-0.0877 (0.0211)	0.0000* (0.0025)	1.0004* (0.0329)	0.0006* (0.0285)	0.0002* (0.0093)	0.0466* (0.7726)	0.1214* (2.0127)
Two-way bilateral imperfect competition	Combined	Φ Θ	-0.0005 (0.0001)	-0.001 (0.00008)	0.4999* (0.0011)	0.4999* (0.0026)	-0.0001* (0.0001)	-0.0009 (0.00008)	-0.0869 (0.0084)	-1.71E72 (2.89E73)	-0.0248 (0.0045)	-0.0001* (0.0009)
	Separated	Ξ Δ	0.5381 (0.0075)	2.29E68 (7.22E69)	-0.3219 (0.0423)	-0.0877 (0.0211)	0.5000* (0.0026)	0.4996* (0.0106)	0.4995* (0.0449)	-0.0000* (0.0070)	0.0335* (0.2988)	0.5484* (0.4347)
Four-way bilateral imperfect competition		Ξ Θ Φ Δ	-0.7944 (0.0159)	0.1433 (0.0077)	-0.5719 (0.0423)	-0.3219 (0.0211)	-0.0877 (0.0024)	0.1047 (0.0017)	0.2514* (0.0467)	0.2508* (0.0259)	0.2867* (0.2049)	0.2712* (0.1188)

Note: numbers in parentheses are standard deviations.
* indicates significant at the 5% significance level.
In the separated model under two-way bilateral imperfect competition framework, processor has oligopoly market power while retailer has oligopsony market power. In the combined model under two-way bilateral imperfect competition framework, processor has oligopoly and oligopsony market power but retailer is price taker.
Ξ and Θ indicate processors' oligopoly and oligopsony power; Φ and Δ indicate retailers' oligopoly and oligopsony power.

Table I-3. Model Selection Tests between True and Alternative Models based on the Likelihood Dominance Criterion

Simulated (True) market structure			Estimated market structure: Perfect competition	Monopoly	Monopsony	Two-way bilateral imperfect competition: Combined	Two-way bilateral imperfect competition: Separated	Four-way bilateral imperfect competition
Perfect competition		H_o	-	739	723	1000	715	713
		H_a	-	141	158	-	125	117
		U	-	120	119	-	160	170
Monopoly		H_o	1000	-	1000	1000	722	589
		H_a	-	-	-	-	140	95
		U	-	-	-	-	138	316
Monopsony		H_o	1000	1000	-	1000	640	603
		H_a	-	-	-	-	79	171
		U	-	-	-	-	-	226
Two-way bilateral imperfect competition	Combined model	H_o	-	-	-	-	-	911
		H_a	1000	1000	1000	-	-	89
		U	-	-	-	-	-	-
	Separated model	H_o	1000	1000	1000	1000	-	501
		H_a	-	-	-	-	-	135
		U	-	-	-	-	-	364
Four-way bilateral imperfect competition		H_o	1000	1000	1000	1000	1000	-
		H_a	-	-	-		-	-
		U	-	-	-		-	-

Note: H_o- simulated market structure, H_a- estimated market structure, and U- undefined

In the separated model under two-way bilateral imperfect competition framework, processor has oligopoly market power while retailer has oligopsony market power. In the combined model under two-way bilateral imperfect competition framework, processor has oligopoly and oligopsony market power but retailer is price taker.

Table I-4. Tests for Market Power Parameter Bias between True and Alternative Models

			Estimated market structure									
					Two-way bilateral imperfect competition							
			Monopoly	Monopsony	Combined		Separated		Four-way bilateral imperfect competition			
			Ξ	Δ	Φ	Θ	Ξ	Δ	Ξ	Θ	Φ	Δ
Simulated (true) market structure			bias	bias	bias	bias	bias	bias	bias	bias	bias	bias
Perfect competition			0.0000 (0.0023)	-0.0000 (0.0005)	-0. 3219* (0.0423)	-0. 0877* (0.0211)	0.0000 (0.0025)	-0.0000 (0.0006)	0.0007 (0.0287)	0.0002 (0.0094)	0.0244 (0.1345)	0.0082 (0.0455)
Monopoly		Ξ	0.0000 (0.0027)	-0.0089* (0.0041)	-0.3219* (0.0423)	-0.0877* (0.0211)	0.0000 (0.0028)	-0.0000 (0.0006)	-0.030 (0.1849)	-1.5E72* (3.3E73)	0.099 (1.8076)	-2.9E46* (8.7E47)
Monopsony		Δ	-0.0003 (0.0086)	0.0003 (0.0313)	-0.3219* (0.0423)	-0.0877* (0.0211)	0.0000 (0.0025)	0.0004 (0.0329)	0.0006 (0.0285)	0.0002 (0.0093)	0.0466 (0.7726)	0.1214 (2.0127)
Two-way bilateral imperfect competition	Combined	Φ Θ	-0.0005* (0.0001)	-0.001* (0.0000)	-0.0000 (0.0011)	-0.0000 (0.0026)	-0.0001 (0.0001)	-0.0009* (0.0000)	-0.087* (0.0084)	-1.7E72* (2. 9E73)	-0.5248* (0.0045)	-0.001 (0.0009)
	Separated	Ξ Δ	0.0381* (0.0075)	2.29E68* (7.22E69)	-0.3219* (0.0423)	-0.0877* (0.0211)	0.0000 (0.0026)	-0.0004 (0.0106)	0.0005 (0.0449)	-0.0000 (0.0070)	0.0335 (0.2988)	0.0484 (0.4347)
Four-way bilateral imperfect competition		Ξ Θ Φ Δ	-1.044* (0.0159)	-0.1067* (0.0077)	-0.5719* (0.0423)	-0.3377* (0.0211)	-0.4320* (0.0024)	-0.1453* (0.0017)	0.0014 (0.0467)	0.0008 (0.0259)	0.0367 (0.2049)	0.0212 (0.1188)

Note: H_o- bias between the estimated market power parameter minus true market power parameter is zero, H_a- bias is not zero.
Values in parentheses are standard deviations.
* indicate that reject the null hypothesis (H_o) at the 5% significant level.
In the separated model under two-way bilateral imperfect competition specification, processor has oligopoly power while retailer has oligopsony power. In the combined model under two-way bilateral imperfect competition, retailer has oligopoly and oligopsony power.
Perfect competition: $\Xi = 0.00, \Theta = 0.00, \Phi = 0.00, \Delta = 0.00$. Monopoly: $\Xi = 1.00, \Theta = 0.00, \Phi = 0.00, \Delta = 0.00$.
Monopsony: $\Xi = 0.00, \Theta = 0.00$, $\Phi = 0.00$, $\Delta = 1.00$. Combined two-way bilateral: $\Xi = 0.00, \Theta = 0.50, \Phi = 0.50, \Delta = 0.00$.
Separated two-way bilateral: $\Xi = 0.50, \Theta = 0.00, \Phi = 0.00, \Delta = 0.50$. Four-way bilateral: $\Xi = 0.25, \Theta = 0.25, \Phi = 0.25, \Delta = 0.25$.

Table I-5. Mean Values and Confidence Intervals for Market Power Index Bias between True and Alternative Models

	Estimated market structures						
	Confidence interval for market power index at 95% significance level						
	Monopoly	Monopsony	Two-way bilateral imperfect competition			Four-way bilateral imperfect competition	
			Combined	Separated			
	M^p	M^r	M^r	M^p	M^r	M^p	M^r
Simulated (true) market structure	(2.5th ,97.5th)	(2.5th , 97.5th)	(2.5th , 97.5th)	(2.5th , 97.5th)	(2.5th , 97.5th)	(2.5th , 97.5th)	(2.5th , 97.5th)
Perfect competition	-0.00 (-0.02, 0.02)	-0.00 (-0.01, 0.01)	1.44* (0.74,2.13)	-0.00 (-0.02, 0.02)	-0.00 (-0.01, 0.01)	0.00 (-0.08, 0.08)	0.01 (-0.28, 0.26)
Monopoly (M^p)	-	-2.29* (-2.35,-2.23)	-5.69* (-8.03, -3.29)	0.00 (-0.01, 0.01)	-2.222* (-2.22, -2.21)	-0.04 (-1.22,0.18)	-2.183* (-3.17, -0.26)
Monopsony (M^r)	-0.87* (-0.90, -.83)	-	-4.337* (-6.68, -1.94)	-0.86* (-0.88,-0.85)	-0.000 (-0.01, 0.01)	-0.87* (-1.11, -0.62)	-0.00 (-0.11, 0.11)
Two-way bilateral imperfect competition — Combined (M^r)	-1.02* (-1.02, -.0.2)	-1.03* (-1.03,-1.03)	-	-1.02* (-1.02,-1.02)	-1.03* (-1.03, -1.03)	-0.02* (-0.02, -0.02)	-1.08* (-1.10, -.06)
Two-way bilateral imperfect competition — Separated (M^p, M^r)	0.08* (0.05,0.11)	-0.15* (-0.20, -0.11)	-4.57* (-6.92, -2.18)	-	-0.34* (-0.34, -0.33)	-0.00 (-0.19, 0.17)	-0.34* (-0.54, -.13)
	0.42* (0.39, 0.46)	0.18* (0.13,0.23)	-4.23* (-6.58, -1.84)	0.34* (0.33, 0.35)	-	0.33* (0.14,0.51)	-0.00 (-0.20, 0.21)
Four-way bilateral imperfect competition (M^p, M^r)	-2.59* (-2.66,-2.52)	-0.34* (-0.37, -0.31)	-4.30* (-6.64, -1.90)	-1.23* (-1.24, -1.22)	-0.42* (-0.42, -0.41)	-	-
	-2.59* (-2.66, -.52)	-0.34* (-0.37, -0.31)	-4.301* (-6.64, -1.90)	-1.23* (-1.24,-1.22)	-0.42* (-0.42, -0.41)	-	-

Note: H_o-bias between the estimated industry index and true industry index is zero, H_a- bias is not zero.
* indicate that the bias of market power index is significantly different zero.
In the separated model under two-way bilateral imperfect competition framework, processor has oligopoly market power while retailer has oligopsony market power. In the combined model, processor has oligopoly and oligopsony market power but retailer is price taker.
M^p indicates that processors' market power index. M^r indicates that retailers' market power index.

APPENDICES

APPENDIX A: Derivations of First order conditions from Profit maximizations of Processors and Retailers Firms.

1. Profit maximization problem for processor *j*:

$$\Pi_j^p = P^p(Y^p)y_j^p - P^f(Y^f)y_j^f - \sum_{m=1}^{3} w_m z_m,$$

$$\frac{\partial \Pi_j^{\mathrm{p}}}{\partial y_j^f} = P^p\left(\frac{\partial y_j^p}{\partial y_j^f}\right) + \left(\frac{\partial P^p}{\partial Y^p}\frac{\partial Y^p}{\partial y_j^p}\frac{\partial y_j^p}{\partial y_j^f}y_j^p\right) - P^f - \left(\frac{\partial P^f}{\partial Y^f}\frac{\partial Y^f}{\partial y_j^f}y_j^f\right) = 0,$$

$$P^p\left(\frac{\partial y_j^p}{\partial y_j^f}\right) + \left(\frac{\partial P^p}{\partial Y^p}\frac{Y^p}{P^p}\frac{\partial Y^p}{\partial y_j^p}\frac{y_j^p}{Y^p}\frac{\partial y_j^p}{\partial y_j^f}P^p\right) - P^f - \left(\frac{\partial P^f}{\partial Y^f}\frac{Y^f}{P^f}\frac{\partial Y^f}{\partial y_j^f}\frac{y_j^f}{Y^f}P^f\right) = 0,$$

$$P^p f_{y_j^f} + \left(\frac{\xi_j}{\varepsilon_d^p} f_{y_j^f} P^p\right) - P^f - \left(\frac{\theta_j}{\varepsilon_s^f}P^f\right) = 0,$$

$$\frac{P^f}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - \frac{P^f}{P^p}\left(\frac{\theta_j}{\varepsilon_s^f}\right).$$

Similarly the marginal products of other inputs are derived for processor *j*.

$$\frac{w_m}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{z_m}, \qquad m = 1, 2, 3.$$

2. Profit maximization problem for retailer *i*.

$$\Pi_i^r = P^r(Y^r)y_i^r - P^p(Y^p)y_i^p - \sum_{k=1}^{3} v_k x_k,$$

$$\frac{\partial \Pi_i^{\mathrm{r}}}{\partial y_i^p} = P^r\left(\frac{\partial y_i^r}{\partial y_i^p}\right) + \left(\frac{\partial P^r}{\partial Y^r}\frac{\partial Y^r}{\partial y_i^r}\frac{\partial y_i^r}{\partial y_i^p}y_i^r\right) - P^p - \left(\frac{\partial P^p}{\partial Y^p}\frac{\partial Y^p}{\partial y_i^p}y_i^p\right) = 0,$$

$$P^r\left(\frac{\partial y_i^r}{\partial y_i^p}\right)+\left(\frac{\partial P^r}{\partial Y^r}\frac{Y^r}{P^r}\frac{\partial Y^r}{\partial y_i^r}\frac{y_i^r}{Y^r}\frac{\partial y_i^r}{\partial y_i^p}P^r\right)-P^p-\left(\frac{\partial P^p}{\partial Y^p}\frac{Y^p}{P^p}\frac{\partial Y^p}{\partial y_i^p}\frac{y_i^p}{Y^p}P^p\right)=0,$$

$$P^r f_{y_i^p}+\left(\frac{\phi_i}{\varepsilon_d^r}f_{y_i^p}P^r\right)-P^p-\left(\frac{\delta_i}{\varepsilon_s^p}P^p\right)=0,$$

$$\frac{P^p}{P^r}=\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{y_i^p}-\frac{P^p}{P^r}\left(\frac{\delta_i}{\varepsilon_s^p}\right).$$

Similarly the marginal products of other inputs are derived for retailer *i*.

$$\frac{v_k}{P^r}=\left(1+\frac{\phi_i}{\varepsilon_d^r}\right)f_{x_k}, \qquad k=1,2,3.$$

APPDENDIX B: Derivation of the Marginal Product for Processors' and Retailers'

1. Derivation of Processors' marginal product of Inputs.

   From equations (28), we have:

$$Y^p=\alpha_{11}Y^f+\alpha_{22}z_1+\alpha_{33}z_2+\alpha_{44}z_3+2\alpha_{12}(Y^f z_1)^{\frac{1}{2}}+2\alpha_{13}(Y^f z_2)^{\frac{1}{2}},$$

$$+2\alpha_{14}(Y^f z_3)^{\frac{1}{2}}+2\left(\alpha_{23}(z_1z_2)^{\frac{1}{2}}+\alpha_{24}(z_1z_3)^{\frac{1}{2}}+\alpha_{34}(z_2z_3)^{\frac{1}{2}}\right).$$

   Marginal products of inputs for processor firm are:

$$f_{Y^f}=\alpha_{11}+\alpha_{12}\left(\frac{z_1}{Y^f}\right)^{\frac{1}{2}}+\alpha_{13}\left(\frac{z_2}{Y^f}\right)^{\frac{1}{2}}+\alpha_{14}\left(\frac{z_3}{Y^f}\right)^{\frac{1}{2}},$$

$$f_{z_1}=\alpha_{22}+\alpha_{12}\left(\frac{Y^f}{z_1}\right)^{\frac{1}{2}}+\alpha_{23}\left(\frac{z_2}{z_1}\right)^{\frac{1}{2}}+\alpha_{24}\left(\frac{z_3}{z_1}\right)^{\frac{1}{2}},$$

$$f_{z_2}=\alpha_{33}+\alpha_{13}\left(\frac{Y^f}{z_2}\right)^{\frac{1}{2}}+\alpha_{23}\left(\frac{z_1}{z_2}\right)^{\frac{1}{2}}+\alpha_{14}\left(\frac{z_3}{z_2}\right)^{\frac{1}{2}},$$

$$f_{z_3}=\alpha_{44}+\alpha_{14}\left(\frac{Y^f}{z_3}\right)^{\frac{1}{2}}+\alpha_{23}\left(\frac{z_1}{z_3}\right)^{\frac{1}{2}}+\alpha_{34}\left(\frac{z_2}{z_3}\right)^{\frac{1}{2}},$$

2. Derivation of Retailers' marginal product of Inputs..

$$Y^r = \beta_{11}Y^p + \beta_{22}x + \beta_{33}x + \beta_{44}x + 2\left(\beta_{12}(Y^p x_1)^{\frac{1}{2}} + \beta_{13}(Y^p x_2)^{\frac{1}{2}} + \beta_{14}(Y^p x_3)^{\frac{1}{2}}\right)$$

$$+2\left(\beta_{23}(x_1 x_2)^{\frac{1}{2}} + \beta_{24}(x_1 x_3)^{\frac{1}{2}} + \beta_{34}(x_2 x_3)^{\frac{1}{2}}\right).$$

Marginal products of inputs for retailer firm are:

$$f_{Y^p} = \beta_{11} + \beta_{12}\left(\frac{x_1}{Y^p}\right)^{\frac{1}{2}} + \beta_{13}\left(\frac{x_2}{Y^p}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{x_3}{Y^p}\right)^{\frac{1}{2}},$$

$$f_{x_1} = \beta_{22} + \beta_{12}\left(\frac{Y^p}{x_1}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_2}{x_1}\right)^{\frac{1}{2}} + \beta_{24}\left(\frac{x_3}{x_1}\right)^{\frac{1}{2}},$$

$$f_{x_2} = \beta_{33} + \beta_{13}\left(\frac{Y^p}{x_2}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_1}{x_2}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{x_3}{x_2}\right)^{\frac{1}{2}},$$

$$f_{x_3} = \beta_{44} + \beta_{14}\left(\frac{Y^p}{x_3}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_1}{x_3}\right)^{\frac{1}{2}} + \beta_{34}\left(\frac{x_2}{x_3}\right)^{\frac{1}{2}}.$$

APPENDIX C: Variance-Covariance Matrix and Parameter Values used in Monte Carlo Simulations

1. Variance-covariance matrix used in generating industry data for five market structures such as: perfect competition, monopoly, monopsony, separated two-way bilateral competition, and four-way bilateral competition

	P^f/P^p	W_1/P^p	W_2/P^p	W_3/P^p	P^p/P^r	V_1/P^r	V_2/P^r	V_3/P^r	Y^p	Y^r
P^f/P^p	0.096									
W_1/P^p	0.011	0.089								
W_2/P^p	0.007	0.049	0.023							
W_3/P^p	-0.000	0.036	0.013	0.062						
P^p/P^r	-0.017	-0.012	-0.014	-0.043	0.040					
V_1/P^r	0.002	0.024	-0.013	0.005	0.037	0.042				
V_2/P^r	0.008	-0.023	0.011	-0.064	0.039	0.049	0.018			
V_3/P^r	0.000	-0.027	-0.007	0.007	0.032	0.032	-0.006	0.004		
Y^p	-0.029	0.004	0.001	-0.002	0.003	0.001	-0.000	-0.002	0.003	
Y^r	0.006	-0.006	0.004	0.005	-0.005	0.003	0.001	-0.001	-0.003	0.013

2. Variance-covariance matrix used in generating industry data for combined two-way bilateral competition

	P^f/P^r	W_1/P^r	W_2/P^r	W_3/P^r	Y^p	Y^{pr}
P^f/P^r	0.033					
W_1/P^r	0.014	0.052				
W_2/P^r	0.018	0.024	0.015			
W_3/P^r	0.009	0.027	0.014	0.038		
Y^p	-0.000	-0.000	-0.000	0.000	0.000	
Y^r	-0.002	-0.001	-0.001	0.001	-0.001	0.012

3. Parameter values (starting values) used in simulations and estimations

Processors		Retailers	
α_{11}	0.838	β_{11}	0.686
α_{22}	0.589	β_{22}	0.703
α_{33}	-1.812	β_{33}	0.163
α_{44}	4.685	β_{44}	0.703
α_{12}	0.248	β_{12}	-0.072
α_{13}	0.224	β_{13}	-0.056
α_{14}	0.034	β_{14}	-0.130
α_{23}	-0.492	β_{23}	0.402
α_{24}	-3.405	β_{24}	0.935
α_{34}	-0.625	β_{34}	1.292

APPENCIX D: Empirical Specification for Simulation and Estimation for Each Market Structure

1. Perfect competition: All market power parameters ($\Xi, \Theta, \Phi,$ and Δ) are to be 0

$$S_1^p = \alpha_{11} + \alpha_{12}\left(\frac{z_1}{Y^f}\right)^{\frac{1}{2}} + \alpha_{13}\left(\frac{z_2}{Y^f}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{z_3}{Y^f}\right)^{\frac{1}{2}},$$

$$S_{z_1}^p = \alpha_{22} + \alpha_{12}\left(\frac{Y^f}{z_1}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_2}{z_1}\right)^{\frac{1}{2}} + \alpha_{24}\left(\frac{z_3}{z_1}\right)^{\frac{1}{2}},$$

$$S_{z_2}^p = \alpha_{33} + \alpha_{13}\left(\frac{Y^f}{z_2}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_1}{z_2}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{z_3}{z_2}\right)^{\frac{1}{2}},$$

$$S_{z_3}^p = \alpha_{44} + \alpha_{14}\left(\frac{Y^f}{z_3}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_1}{z_3}\right)^{\frac{1}{2}} + \alpha_{34}\left(\frac{z_2}{z_3}\right)^{\frac{1}{2}},$$

$$S_1^r = \beta_{11} + \beta_{12}\left(\frac{x_1}{Y^p}\right)^{\frac{1}{2}} + \beta_{13}\left(\frac{x_2}{Y^p}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{x_3}{Y^p}\right)^{\frac{1}{2}},$$

$$S_{x_1}^r = \beta_{22} + \beta_{12}\left(\frac{Y^p}{x_1}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_2}{x_1}\right)^{\frac{1}{2}} + \beta_{24}\left(\frac{x_3}{x_1}\right)^{\frac{1}{2}},$$

$$S_{x_2}^r = \beta_{33} + \beta_{13}\left(\frac{Y^p}{x_2}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_1}{x_2}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{x_3}{x_2}\right)^{\frac{1}{2}},$$

$$S_{x_3}^r = \beta_{44} + \beta_{14}\left(\frac{Y^p}{x_3}\right)^{\frac{1}{2}} + \beta_{23}\left(\frac{x_1}{x_3}\right)^{\frac{1}{2}} + \beta_{34}\left(\frac{x_2}{x_3}\right)^{\frac{1}{2}}.$$

2. Monopoly: Processors only have market power in selling processed product to retailers which assumed perfectly competitive.

$$S_1^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right)\left(\alpha_{11} + \alpha_{12}\left(\frac{z_1}{Y^f}\right)^{\frac{1}{2}} + \alpha_{13}\left(\frac{z_2}{Y^f}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{z_3}{Y^f}\right)^{\frac{1}{2}}\right),$$

$$S_{z_m}^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_m},$$

$$S_1^r = f_{y^p}, \qquad S_{x_k}^r = f_{X_k}.$$

3. Monopsony: Retailers only have market power in procuring processed product from processors which behave perfectly.

$$S_1^p = f_{y^f}, \qquad S_{z_m}^p = f_{Z_m},$$

$$S_1^r = \frac{\left(\beta_{11} + \beta_{12}\left(\frac{x_1}{Y^p}\right)^{\frac{1}{2}} + \beta_{13}\left(\frac{x_2}{Y^p}\right)^{\frac{1}{2}} + \beta_{14}\left(\frac{x_3}{Y^p}\right)^{\frac{1}{2}}\right)}{\left(1 + \frac{\Delta}{\varepsilon_s^p}\right)}, \quad S_{x_k}^r = f_{X_k}.$$

4. Separated two-way bilateral imperfect competition: processors only have oligopoly power in selling processed product to retailers and retailers, also, only has oligopsony power in procuring processed product from processors.

$$S_1^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{y^f}, \qquad S_{Z_m}^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_m},$$

$$S_1^r = \frac{f_{y^p}}{\left(1+\frac{\Delta}{\varepsilon_s^p}\right)}, \qquad S_{x_k}^r = f_{X_k}.$$

5. Combined two-way bilateral imperfect competition: retailers and processors are integrated in a single 'processing/retailing' sector, which competes imperfectly in procuring farm inputs from a perfectly competitive farm sector and in selling processed product to consumers.

$$\Pi^{rp} = P^{rp}(Y^{rp})y^{rp} - P^f(Y^f)y^f - \sum_{m=1}^{3} w_m z_m.$$

The first order condition is:

$$\frac{P^f}{P^{rp}} = \left(1 + \frac{\phi}{\varepsilon_d^{rp}}\right) f_{y^f} - \frac{P^f}{P^{rp}}\frac{\theta}{\varepsilon_s^f}, \qquad \frac{w_m}{P^{rp}} = \left(1 + \frac{\phi}{\varepsilon_d^{rp}}\right) f_{Z_m}.$$

Rearrange with the share equation, then

$$S_1^{rp} = \frac{\left(1+\frac{\Phi}{\varepsilon_d^{rp}}\right) f_{Y^f}}{\left(1+\frac{\Theta}{\varepsilon_s^f}\right)}, \qquad S_{Z_m}^{rp} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right) f_{Z_m}.$$

Therefore, the industry share equations are;

$$S_1^{rp} = \frac{\left(1+\frac{\Phi}{\varepsilon_d^{rp}}\right)}{\left(1+\frac{\Theta}{\varepsilon_s^f}\right)} \left(\alpha_{11} + \alpha_{12}\left(\frac{z_1}{Yf}\right)^{\frac{1}{2}} + \alpha_{13}\left(\frac{z_2}{Yf}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{z_3}{Yf}\right)^{\frac{1}{2}}\right),$$

$$S_{z_1}^{rp} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right)\left(\alpha_{22} + \alpha_{12}\left(\frac{Y^f}{z_1}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_2}{z_1}\right)^{\frac{1}{2}} + \alpha_{24}\left(\frac{z_3}{z_1}\right)^{\frac{1}{2}}\right),$$

$$S_{z_2}^{rp} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right)\left(\alpha_{33} + \alpha_{13}\left(\frac{Y^f}{z_2}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_1}{z_2}\right)^{\frac{1}{2}} + \alpha_{14}\left(\frac{z_3}{z_2}\right)^{\frac{1}{2}}\right),$$

$$S_{z_3}^{rp} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right)\left(\alpha_{44} + \alpha_{14}\left(\frac{Y^f}{z_3}\right)^{\frac{1}{2}} + \alpha_{23}\left(\frac{z_1}{z_3}\right)^{\frac{1}{2}} + \alpha_{34}\left(\frac{z_2}{z_3}\right)^{\frac{1}{2}}\right),$$

where, $S_{z_m}^{rp} = \frac{w_m}{P^{rp}}$ is the share equation for the input.

6. Four-way bilateral imperfect competition: Bothe processors and retailers have oligopoly/oligopsony market power in output and input market.

$$S_1^p = \frac{\left(1+\frac{\Xi}{\varepsilon_d^p}\right)}{\left(1+\frac{\Theta}{\varepsilon_s^f}\right)} f_{y^f}\ , \qquad S_{z_m}^p = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_m},$$

$$S_1^r = \frac{\left(1+\frac{\Phi}{\varepsilon_d^r}\right)}{\left(1+\frac{\Delta}{\varepsilon_s^p}\right)} f_{y_p}\ , \qquad S_{x_k}^r = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{X_k}.$$

CHAPTER II

ESTIMATING PROCESSORS' AND RETAILERS' MARKET POWER IN THE U.S. BEEF INDUSTRY

Introduction

The structure of the U.S. beef industry has significantly changed in recent years. At the farm level, a multi-year drought in the Southern Plains caused high feed prices and large financial losses, and as a result, many small cattle feeders went out of business. At the processor level, the beef packing industry has increasingly concentrated. The market share of the largest four packers has been increased from 78% to 85% for the period from 1998 to 2010. Furthermore, at the retail level, sales by the 20 largest food retailers have increased from 39.2% in 1992 to 64.2 % of total U.S. grocery sales in 2009 (ERS, USDA). Therefore, it is not surprising that the possibility of non-competitive market conduct exists in both beef processing and retail industries.

Most studies in the industrial organization literature assume that processors have potential oligopoly and/or oligopsony market power (Azzam and Schroeter 1995; Azzam 1997; Paul 2001; Lopez, Azzam and Espana 2002). These studies tend to focus on processors alone and assume that market power exercise is limited to firms on one side of the market.

A few studies consider the possibility that a single firm may exert market power simultaneously in both output and input markets (Schroeter 1988; Atkinson and Kerkvliet 1989; Azzam and Pagoulatos 1990; Mei and Sun 2008). In these studies, an integrated firm representing both processors and retailers is allowed to exercise market power in both output and input markets, while firms on the other side of the transaction, for example, input providers including cattle producers, are set to be perfectly competitive. Recent studies consider bilateral relationship between processors and retailers and measure their potential market power exertion (Raper, Love and Shumway 2000; Chung and Tostao 2012). Although these studies consider bilateral relationship between processors and retailers with more flexible models, in each case, processors and retailers are assumed to be perfectly competitive at least one side of the transaction. Furthermore, in these studies, conjectural elasticities of output and input markets are restricted to be identical because the production technology is restricted to fixed proportions between the output and input.

The objective of this study is to measure the degrees of market power in the U.S. beef industry while considering the full range of bilateral imperfect competition between processors and retailers. Specifically, we separate processors from the integrated processor-retailer sector that are typically used in many previous studies and consider separate market power parameters for input and output markets of processing and retail sectors. Therefore, both oligopoly and oligopsony market power are estimated for retailers and processors, separately. Unlike many previous studies, our study uses the primal production function approach without restricting conjectural elasticities in output and input markets to be identical. After estimating conjectural elasticities from input and output markets, market power index[1] that is similar to the Lerner index is derived and estimated to reflect both buying and selling sides of an industry market power. Finally, our study investigates the sensitivity[2] of our results using alternative functional forms of production function. We estimate market power parameters and market power indices with three different functional forms of productions such as transcendental logarithmic (TL), generalized Leontief (GL), and normalized quadratic (NQ) functional forms.

Empirical results show that processors and retailers exercise market power in both input and output markets in the U.S. beef industry. Furthermore, estimated market power parameters and market power indices are sensitive to the choice of market structures and functional forms.

Literature Review

Many researchers have used the new empirical industrial organization (NEIO) framework to investigate market power issues in agricultural industries (Azzam and Schroeter 1995; Azzam 1997; Paul 2001; Lopez, Azzam and Espana 2002). Azzam and Schroeter (1995) models the tradeoff between oligopsony power and cost efficiency resulting from in the beef packing industry and find that non-competitive effects of consolidation are about half the actual cost savings from scale economies. Azzam (1997) estimates oligopsony market power effects and cost efficiency effect for the U.S. beef packing industry and show that the cost efficiency effect is larger than oligopsony market power effect. Paul (2001) measures packers' market power in the beef input market and cost (utilization, scale, and scope) economies using monthly cost and revenue data from a survey of the forty-three largest U.S. beef packing plants between 1992 to 1993. Lopez, Azzam and Espana (2002) develop the oligopoly model similar to the Azzam's oligopsony model to estimate market power effects and efficiency effects in 32 U.S. food processing industries and finds that oligopoly power effects outweigh cost efficiency effects in the meat packing industry. These studies only consider processors' oligopoly and/or oligopsony power and find some level of market power in the U.S. beef processing industry.

A few studies (Schroeter 1988; Chung and Tostao 2012) consider the possibility of imperfect competition in both output and input markets. Schroeter (1988) considers the possibility that a single firm may exert market power simultaneously in both its output and input markets, but in each case, processors' and retailers' firms are assumed to be price takers. Chung and Tostao (2012) consider the bilateral relationship between processors and retailers. Model constructs from integrated processor-retailer model separately and estimate the tradeoff between market power and cost efficiency. They find that cost efficiency gains dominate potential oligopoly market power effects from increased concentration in the U.S. beef industry. Although these studies consider and examine the potential market power in input and output markets, the models developed in these studies are yet not flexible enough to consider the full range of the bilateral market power relationship. These models do not allow one to estimate the potential market power of retailers and processors separately in each of input and output markets. Furthermore, these studies use the dual cost function approach and have restrictions in deriving an expression for conjectural elasticity in the input market unless the production technology assumed fixed proportions between output and input.

Since the dual (cost function) approach has arguments deriving an expression for conjectural elasticity in input market, a few studies consider a production function approach that allows different conjectural elasticities in input and output markets without the symmetry assumption (Azzam and Pagoulatos 1990; Chang and Tremblay 1991). Azzam and Pogoulatos (1990) extend the traditional conjectural approach to the analysis of imperfect competition in output and input markets simultaneously. This study separately derives conjectural elasticities in imperfect input and output markets and estimates the market power effects for the U.S. meat packing industry. Findings indicate that the industry is imperfectly competitive in both input and output markets. The degree of non-competitiveness is similar in both markets but the market power in input market is significantly higher than that in output market. Chang and Tremblay (1991) provide the theoretical analysis of oligopsony and oligopoly in input and output markets and develops the firm and market power index to measure oligopsony and oligopoly market power. Although these studies make contributions towards understanding of imperfect competition, these studies do not consider potential bilateral market power effects between retailers and processors. These studies have *a priori* assumptions regarding the direction of market power exertion unless distinguished the conjectural elasticities in the output and input markets to be identical.

Our study measures degrees of market power in the U.S. beef industry, but differs from previous studies in four areas. First, we consider processors' and retailers' profit maximization problems separately and develop by far the most flexible model that considers full range of the bilateral market power relationship between retailers and processors. Therefore, unlike previous studies, the flexible model developed in this study estimates four conjectural elasticities that reflect potential oligopoly and oligopsony power for processors and retailers, separately. Second, our model is based on the production function approach so that it does not require the symmetry assumption on conjectural elasticities between input and output markets. Most previous studies are based on the dual approach which requires identical conjectural elasticities of factor and output markets under the fixed proportions technology assumption. Third, our study estimates market power indices which reflect both buying and selling sides of an industry market power. Finally, a sensitivity analysis is conducted to examine if our finding are sensitive to alternative functional forms of production function

Theoretical Framework

In general, there are two approaches in the theoretical framework of conjectural elasticity in the literature. One is the primal production function-based approach (Azzam and Pagoulatos 1990; Chang and Tremblay 1991; Mei and Sun 2008) and the other is the dual cost function-based approach (Schroeter 1988; Azzam 1997; Lopez, Azzam and Espana 2002; Chung and Tostao 2012). In this paper, the primal production function approach is used because it is not imposing that conjectural elasticities between input and output market are to be identical.

Consider a processor firm that uses a vector of inputs, z, with associated prices, w, to produce a single output, y^p. The j^{th} firm's production function can be stated as:

(1) $$y_j^p = f(y_j^f, z_{uj}),$$

where y_j^p is the output produced, y_j^f is the farm input, z_{uj} (u=1, …, U.) represents non-farm inputs like as labor, capital, and material that is purchased from a competitive market. Furthermore, assume each firm exercises some degree of market power in purchasing the farm input y_j^f and in selling its output, y_j^p to retailers. Let the inverse market demand curve facing the industry in its output market be given by:

(2) $$P^p = f(Y^p),$$

where Y^p is the total industry output, and P^p is the price per unit of the processed output. The inverse market supply function for specific factor input is given by:

(3) $$P^f = h(Y^f),$$

where P^f and $Y^f = \sum_{j=1}^{N} y_j^f$ are farm input price and total industry input with *N* number of farmers. Denoting the price of non-farm inputs by $w_1, \ldots, w_m$, and assuming each firm is a profit maximizing. The profit maximization problem for the *j*[th] firm can be presented as:

(4) $$Max\ \Pi_j^p = P^p(Y^p)y_j^P - P^f(Y^f)y_j^f - \sum_{u=1}^{M} w_u z_{uj}.$$

The first order conditions corresponding to this profit maximization problem are given by:

(5) $$\frac{\partial \Pi_j^P}{\partial y_j^f} = P^p\left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - P^f - P^f\left(\frac{\theta_j}{\varepsilon_s^f}\right) = 0,$$

(6) $$\frac{\partial \Pi_j^P}{\partial z_{uj}} = P^p\left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - w_u = 0,$$

or

(7) $$\frac{P^f}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - \frac{P^f}{P^p}\left(\frac{\theta_j}{\varepsilon_s^f}\right),$$

(8) $$\frac{w_u}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{z_{uj}}, \qquad j = 1, \ldots, N \text{ and } u = 1, \ldots, U,$$

where $\xi_j = \frac{\partial Y^p}{\partial y_j^p}\frac{y_j^p}{Y^p}$ is the j^{th} firm's conjectural elasticity in the output market;

$\theta_j = \frac{\partial Y^f}{\partial y_j^f}\frac{y_j^f}{Y^f}$ is the j^{th} firm's conjectural elasticity in the farm input market;

$\varepsilon_d^p = -\frac{\partial Y^p}{\partial P^p}\frac{P^p}{Y^p}$ is the price elasticity of output demand;

$\varepsilon_s^f = \frac{\partial Y^f}{\partial P^f}\frac{P^f}{Y^f}$ is the price elasticity of the farm input supply;

$f_{y_j^f} = \frac{\partial y_j^p}{\partial y_j^f}$ is the marginal product of the farm input used by firm *j*;

and $f_{z_{mj}} = \frac{\partial y_j^p}{\partial z_{uj}}$ is the marginal product of the u^{th} input used by firm *j*.

Now, Consider a retailer firm that uses a vector of inputs, x, with associated prices, v, to produce a single output, y^r, for sale to consumers. Let the i^{th} firm's production function is defined as:

(9) $$y_i^r = f\left(y_i^p, x_{ki}\right),$$

where y_i^r is retail output, y_i^p is the processed input, x_{ki} (*k=1,…, K*) represent other inputs such as labor, capital, and materials that are purchased from competitive markets. The inverse market demand function is given by:

(10) $$P^r = f(Y^r),$$

where $Y^r = \sum_{i=1}^{N} y_i^r$ is the total industry output, and P^r is the price per unit of the retail output. The inverse market supply of the specific factor is given by:

(11) $$P^p = g(Y^p),$$

where P^p and $Y^p = \sum_{i=1}^{N} y_i^p$ are market processed input price and total industry input with N number of processors. Denoting the price of inputs by $v_1, \dots, v_k$, and assuming each firm is a profit maximize.

The profit maximization problem for the i^{th} firm can be stated as:

(12) $$Max\ \Pi_i^r = P^r(Y^r)y_i^r - P^p(Y^p)y_i^p - \sum_{k=1}^{3} v_k x_{ki}.$$

Then, the first order conditions corresponding to this profit maximization problem are:

(13) $$\frac{\partial \Pi_j^r}{\partial y_i^p} = P^r\left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{y_i^p} - P^p - P^p\left(\frac{\delta_i}{\varepsilon_s^p}\right) = 0,$$

(14) $$\frac{\partial \Pi_i^r}{\partial x_{ki}} = P^r\left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{x_{ki}} - v_k = 0,$$

or

(15) $$\frac{P^p}{P^r} = \left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{y_i^p} - \frac{P^p}{P^r}\left(\frac{\delta_i}{\varepsilon_s^p}\right),$$

(16) $$\frac{v_k}{P^r} = \left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{x_{ki}}, \qquad i = 1, \dots, N \text{ and } k = 1, \dots, K,$$

where $\phi_i = \frac{\partial Y^r}{\partial y_i^r}\frac{y_i^r}{Y^r}$ is the i^{th} retailer firm's conjectural elasticity in the output market;

$\delta_i = \frac{\partial Y^p}{\partial y_i^p}\frac{y_i^p}{Y^p}$ is the i^{th} retailer firm's conjectural elasticity in the input market;

$\varepsilon_d^r = -\frac{\partial Y^r}{\partial P^r}\frac{P^r}{Y^r}$ is the price elasticity of output demand;

$\varepsilon_s^p = \frac{\partial Y^p}{\partial P^p}\frac{P^p}{Y^p}$ is the price elasticity of the processed input supply;

$f_{y_i^p} = \frac{\partial y_i^r}{\partial y_i^p}$ is the marginal product of the processed input used by firm i;

and $f_{x_{ki}} = \frac{\partial y_i^r}{\partial x_{ki}}$ is the marginal product of the n^{th} input used by firm i.

The conjectural elasticities, $\xi_j, \theta_j, \phi_i,$ and δ_i provide useful benchmarks for testing for competitive behavior and allow one to carry out various tests about market

(Appelbaum 1982; Azzam and Pagoulatos 1990). The parameter $\xi_j \in [0,1]$ and $\delta_i \in [0,1]$ measure the departures from competition in selling the output. $\theta_j \in [0,1]$ and $\phi_i \in [0,1]$ measure the departures from competition in buying the input. If both ξ_j and θ_j are equal to 0 in equations (7) and (8), we have the perfectly competitive case where each firm equates the value of marginal product of an input to the perceived marginal cost of the input. In the extreme case where both ξ_j and θ_j are equal to 1, we obtain the monopoly and monopsony case. Other combinations of market structures denote various degrees of oligopoly/oligopsony power with higher values of both ξ_j and θ_j indicating greater departures from competitive behavior. The parameters ϕ_i and δ_i play a similar role in terms of retailing sector, denoting possible perfect competition, monopoly/monopsony case and various degrees of oligopoly and oligopsony power.

To measure the degree of market power in input and output markets, Chang and Tremblay (1991) develop and define an oligopoly/oligopsony index (market power index) for firm and industry level. This approach is similar to that developed by Lerner (1932), who defined the index of monopoly price distortion as the difference between the output price and marginal cost divided by the price. The market power index is the difference between the value of the marginal product and the input price all divided by the value of the marginal product. The market power index for processor firm *j* is derived such as:

(17) $$M_j^p = \left[P^P\left(MP_{y_j^f}\right) - P^f\right] / \left[P^P\left(MP_{y_j^f}\right)\right].$$

Rearranging this equation with market power parameters yields:

(18) $$M_j^p = \left(\frac{\theta_j}{\varepsilon_s^f} + \frac{\xi_j}{\varepsilon_d^p}\right) / \left(1 + \frac{\theta_j}{\varepsilon_s^f}\right).$$

Because the value of the marginal product must be greater than or equal to P^f which is greater than zero, the value of M_j^p ranges from 0 to 1. When the factor is paid equal to the value of its marginal product, $P^P\left(MP_{y_j^f}\right) = P^f$, $M_j^p = 0$ and the markets are allocated efficiently. As the difference in the value of the marginal product and the factor price increases, M_j^p approaches 1. Thus, greater inefficiency is implied by the higher values of M_j^p. In the processor sector, $\frac{\xi_j}{\varepsilon_d^p}$ reflects the non-competitive performance in the output market and reduces to the well-known Lerner index of $\frac{1}{\varepsilon_d^p}$ for the pure monopolist. $\frac{\theta_j}{\varepsilon_s^f}$ reflects the non-competitive performance in the input market and reduces to $\frac{1}{\varepsilon_s^f}$ for the pure monopsonist. The market power index is quite general because no restrictions are imposed on the conjectural elasticities of the firm (i.e., they may range from perfectly competitive to collusive). The index for retailers is obtained in an analogous manner for firm level and plays a similar role. The index for retailer firm *i* is derived such as:

(19) $$M_i^r = \left(\frac{\delta_i}{\varepsilon_s^p} + \frac{\phi_i}{\varepsilon_d^r}\right) / \left(1 + \frac{\delta_i}{\varepsilon_s^p}\right).$$

In practice, the absence of firm-level data generally requires an additional assumption to make the preceding analysis relevant to the behavior of the industry as whole. We assume that at equilibrium, conjectural elasticities in processing and retail sectors are invariant across firms, i.e., $\xi_1 = \xi_2 = \cdots = \Xi$, and $\theta_1 = \theta_2 = \cdots = \Theta$. The conjectural elasticities in the retailing sector, also, are invariant across the firm $\phi_1 =$

$\phi_2 = \cdots = \Phi$ and $\delta_1 = \delta_2 = \cdots = \Delta$. Then, the aggregate analogue of the optimality condition in processing and retailing sector can be written as:

(20) $$\frac{P^f}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Y^f} - \frac{P^f}{P^p}\frac{\Theta}{\varepsilon_s^f},$$

(21) $$\frac{W_u}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_u},$$

(22) $$\frac{P^p}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{Y^p} - \frac{P^p}{P^r}\frac{\Delta}{\varepsilon_s^p},$$

(23) $$\frac{V_k}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{X_k}.$$

Therefore, the industry-level market power index for processors and retailers can be stated as:

(24) $$M^{p^*} = \left(\frac{\Theta}{\varepsilon_s^f} + \frac{\Xi}{\varepsilon_d^p}\right) / \left(1 + \frac{\Theta}{\varepsilon_s^f}\right),$$

(25) $$M^{r^*} = \left(\frac{\Delta}{\varepsilon_s^p} + \frac{\Phi}{\varepsilon_d^r}\right) / \left(1 + \frac{\Delta}{\varepsilon_s^p}\right).$$

Empirical Procedures

While various possibilities of retailer-processor vertical interactions exist, we consider the following three cases to compare results of the full-range bilateral market power model with those of traditional NEIO models. First, processors and retailers are assumed to be integrated in a single ‘processing-retailing’ sector that is allowed to have oligopoly and oligopsony market power (e.g., Schroeter 1988; Azzam and Pagoulatos 1990; Mei and Sun 2008) . Second, retailers are only allowed to have oligopsony power, but processors are only allowed to have oligopoly power (e.g., Raper, Love and Shumway 2000). Finally, retailers are allowed to have both oligopoly and oligopsony power, and processors are also allowed to possess both oligopsony and oligopoly power.

Case 1. Imperfect competition in a single 'processing/retailing' sector

In this case, retailers and processors are combined in a single 'processing/retailing' sector, which competes imperfectly in procuring farm inputs from a perfectly competitive farm sector and in selling processed product to consumers[3].

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

$$max\, \Pi^{rp} = P^{rp}(Y^{rp})y_i^{rp} - P^f(Y^f)y_i^f - \sum_{u=1}^{3} w_u z_{ui}, \tag{26}$$

where y^{rp}, P^{rp} and P^f are retailer output, retail output price and farm input price, respectively. The total supply of processed output is represented by $Y^{rp} = \sum_{i=1}^{N} y_i^{rp}$. The first order condition for this maximization problem is:

$$\frac{\partial \Pi^{rp}}{\partial y_i^f} = P^{rp}\left(1 + \frac{\phi_i}{\varepsilon_d^{rp}}\right) f_{y_i^f} - P^f - P^f\left(\frac{\theta_i}{\varepsilon_s^f}\right) = 0, \tag{27}$$

$$\frac{\partial \Pi^{rp}}{\partial z_{ui}} = P^{rp}\left(1 + \frac{\phi_i}{\varepsilon_d^{rp}}\right) f_{y_i^f} - w_u = 0. \tag{28}$$

Rearranging equations (27) and (28), we obtain:

$$\frac{P^f}{P^{rp}} = \left(1 + \frac{\phi_i}{\varepsilon_d^{rp}}\right) f_{y_i^f} - \frac{P^f}{P^{rp}}\left(\frac{\theta_i}{\varepsilon_s^f}\right), \tag{29}$$

$$\frac{w_u}{P^{rp}} = \left(1 + \frac{\phi_i}{\varepsilon_d^{rp}}\right) f_{z_{ui}}, \qquad u = 1, 2, 3, \tag{30}$$

where $\phi_i = \frac{\partial Y^{rp}}{\partial y_i^{rp}} \frac{y_i^{rp}}{Y^{rp}}$ is the firm i^{th} conjectural elasticity in the output market;

$\theta_i = \frac{\partial Y^f}{\partial y_i^f}\frac{y_i^f}{Y^f}$ is the firm i^{th} conjectural elasticity in the farm input market;

$\varepsilon_d^{rp} = -\frac{\partial Y^{rp}}{\partial P^{rp}}\frac{P^{rp}}{Y^{rp}}$ is the price elasticity of output demand;

$\varepsilon_s^f = \frac{\partial Y^f}{\partial P^f}\frac{P^f}{Y^f}$ is the price elasticity of the farm input supply;

$f_{y_i^f} = \frac{\partial y_i^{rp}}{\partial y_i^f}$ is the marginal product of the farm input used by firm *i*;

and $f_{z_{ui}} = \frac{\partial y^{rp}}{\partial z_{ui}}$ is the marginal product of the u^{th} input used by firm *i*.

To estimate these equations at the industry level, we assume that the conjectural elasticities are invariant across firms due to the absence of price and quantity data at the firm level. Then, from equations (29) and (30), we have:

(31) $$\frac{P^f}{P^{rp}} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right) f_{Y^f} - \frac{P^f}{P^{rp}}\left(\frac{\Theta}{\varepsilon_s^f}\right),$$

(32) $$\frac{w_u}{P^{rp}} = \left(1 + \frac{\Phi}{\varepsilon_d^{rp}}\right) f_{z_u}, \qquad u = 1, 2, 3.$$

Case 2. Two-way bilateral imperfect competition

In this case, retailers have oligopsony power in procuring processed output from processors while processors are allowed to have oligopoly power in selling processed output to retailers. Case 2 is different from Case 1 because Case 2 considers retailers and processors separately. This bilateral oligopoly and oliopsony model is similar to the model considered in the previous study (Raper, Love, and Shumway 2000). First, the profit maximization problem for a representative processor is presented as:

(33) $$Max\ \Pi_j^p = P^p(Y^p)y_j^P - P^f(Y^f)y_j^f - \sum_{u=1}^{3} w_u z_{uj}.$$

The first-order necessary condition for the maximization problem is given by:

(34) $$\frac{\partial \Pi^p}{\partial y_j^f} = P^p \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - P^f = 0,$$

(35) $$\frac{\partial \Pi^p}{\partial Z_{uj}} = P^p \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{Z_{uj}} - w_u = 0.$$

Rearranging equations (34) and (35) gives:

(36) $$\frac{P^f}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f},$$

(37) $$\frac{w_u}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{Z_{uj}}, \qquad u = 1, 2, 3.$$

Secondly, the retailers' profit maximization problem is defined as:

(38) $$Max\ \Pi_i^r = P^r(Y^r) y_i^r - P^p(Y^p) y_i^p - \sum_{k=1}^{3} v_k x_{ki}.$$

The first-order necessary condition corresponding to this profit maximization problem is:

(39) $$\frac{\partial \Pi^r}{\partial y_i^p} = P^r f_{y_i^p} - P^p - P^p \left(\frac{\delta_i}{\varepsilon_s^p}\right) = 0,$$

(40) $$\frac{\partial \Pi^r}{\partial x_k} = P^r f_{x_{ki}} - v_k = 0.$$

Rearranging equations (39) and (40) gives:

(41) $$\frac{P^p}{P^r} = f_{y_i^p} \Big/ \left(1 + \frac{\delta_i}{\varepsilon_s^p}\right),$$

(42) $$\frac{v_k}{P^r} = f_{x_{ki}}, \qquad k = 1, 2, 3.$$

Imposing an assumption of symmetric conjectural elasticities in equations (36), (37), (41) and (42), we have industry share equations as:

(43) $$\frac{P^f}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Y^f},$$

(44) $$\frac{W_u}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_u},$$

(45) $$\frac{P^p}{P^r} = f_{Y^p} \,/ \left(1 + \frac{\Delta}{\varepsilon_s^p}\right),$$

(46) $$\frac{V_k}{P^r} = f_{X_k}, \qquad k = 1, 2, 3.$$

Case 3. Four-way bilateral imperfect competition

This is the most flexible framework to consider the full range of bilateral imperfect competition. Retailers and processors are allowed to exercise oligopoly and oligopsony power in both procuring inputs and selling output. Therefore, in this case, four conjectural elasticities are expected to be estimated from the model to represent potential oligopoly and oligopsony power of retailers and processors. This bilateral imperfect competition model nests the retailer sector of Case II and the processor sector of Case III of Chung and Tostao (2012). The profit maximization problem for a representative processor is defined as:

(47) $$Max\ \Pi_j^p = P^p(Y^p)y_j^P - P^f(Y^f)y_j^f - \sum_{u=1}^{3} w_u z_{uj}.$$

The first-order necessary condition for the maximization problem is:

(48) $$\frac{\partial \Pi^p}{\partial y_j^f} = P^p\left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - P^f - P^f\left(\frac{\theta_j}{\varepsilon_s^f}\right) = 0,$$

(49) $$\frac{\partial \Pi^p}{\partial z_{uj}} = P^p\left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - w_u = 0,$$

or

(50) $$\frac{P^f}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{y_j^f} - \frac{P^f}{P^p}\left(\frac{\theta_j}{\varepsilon_s^f}\right),$$

(51) $$\frac{w_u}{P^p} = \left(1 + \frac{\xi_j}{\varepsilon_d^p}\right) f_{z_{uj}}, \qquad u = 1, 2, 3.$$

The profit maximization problem for the retailer is defined as:

(52) $$Max\ \Pi_i^r = P^r(Y^r)y_i^r - P^p(Y^p)y_i^p - \sum_{k=1}^{3} v_k x_{ki}.$$

The first-order necessary conditions corresponding to this profit maximization problem are:

(53) $$\frac{\partial \Pi^r}{\partial y_i^p} = P^r\left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{y_i^p} - P^p - P^p\left(\frac{\delta_i}{\varepsilon_s^p}\right) = 0,$$

(54) $$\frac{\partial \Pi^r}{\partial x_{ki}} = P^r\left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{x_{ki}} - v_k = 0,$$

or

(55) $$\frac{P^p}{P^r} = \left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{y_i^p} - \frac{P^p}{P^r}\left(\frac{\delta_i}{\varepsilon_s^p}\right),$$

(56) $$\frac{v_k}{P^r} = \left(1 + \frac{\phi_i}{\varepsilon_d^r}\right) f_{x_{ki}}, \qquad k = 1, 2, 3.$$

Then, with the symmetry assumption in conjectural elasticities, industry share equations are:

(57) $$\frac{P^f}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Y^f} - \frac{P^f}{P^p}\left(\frac{\Theta}{\varepsilon_s^f}\right),$$

(58) $$\frac{W_u}{P^p} = \left(1 + \frac{\Xi}{\varepsilon_d^p}\right) f_{Z_u}, \qquad u = 1, 2, 3,$$

(59) $$\frac{P^p}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{Y^p} \; - \frac{P^p}{P^r}\left(\frac{\Delta}{\varepsilon_s^p}\right),$$

(60) $$\frac{V_k}{P^r} = \left(1 + \frac{\Phi}{\varepsilon_d^r}\right) f_{X_k}, \qquad k = 1, 2, 3.$$

Selecting Functional Forms

Many studies estimating the degree of market power use the Leontief type technology. However, several studies in the literature (e.g., Love and Shumway 1994; Azzam and Pagoulatos 1991; and Sexton 2000) suggest that market power estimates could be sensitive to selected functional forms. Our study considers three different types of functional forms for a sensitivity analysis on estimates of market power parameters and market power indices. The three flexible functional forms selected for this analysis include transcendental logarithmic (TL), generalized Leontief (GL), and normalized quadratic (NQ) functional forms[4]. These three functions satisfy the Diewert flexibility[5] and may be interpreted as second-order Taylor-series expansions about different points with different transformations of variables (Thompson 1988).

Transcendental Logarithmic (TL) production function

The Transcendental Logarithmic (TL) production function (Christensen, Jorgenson, and Lau 1973) is one of the most flexible often used functional forms in empirical studies. It does not assume the rigid premise of perfect or “smooth” substitution between production factors or perfect competition in the production factor market but permits to pass from a linear relationship between output and production factors. Due to its properties, the TL production function can be used for the second order approximation of a linear homogenous production. The TL function for the processor that uses a vector of inputs, Z, to produce a single output, Y^p, for sale as an input to retailers is given as:

$$lnY^p = \alpha_0 + \sum_{i=1}^{4} \alpha_i lnZ_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} \alpha_{ij} lnZ_i lnZ_j, \quad (61)$$

where Z includes total industry inputs of farm input(Y^f) , labor (Z_l), capital (Z_c), and material (Z_m), Y^p is total processed industry output of beef products. The TL is symmetric in coefficients, i.e., $\alpha_{ij} = \alpha_{ji}$. From equation (61), the marginal product the i^{th} input is:

$$f_{Z_i} = \left(\alpha_i + \sum_{j=1}^{4} \alpha_{ij} lnZ_j\right)\frac{Y^p}{Z_i}. \quad (62)$$

Equations (62) is used to estimate share equations at the industry level for an integrated processor/retailer sector of Case 1, and processor sector of cases 2 and 3. Similarly, the marginal product of the k^{th} input in producing a retailers' output Y^r is derived as:

$$f_{X_k} = \left(\beta_k + \sum_{h=1}^{4} \beta_{kh} lnX_k\right)\frac{Y^r}{X_k}, \quad (63)$$

where X includes total industry inputs of farm input(Y^p) , labor (Z_l), capital (Z_c), and material (Z_m). Equation (63) is applied to retailer share equations of cases 2 and 3 for empirical estimation.

Generalized Leontief (GL) production function

The generalized Leontief (GL) production function (Diewert 1971) is another flexible functional form that permits partial elasticities of substitution between inputs to vary. A processor's GL production function that uses a vector of inputs, Z, to produce a single output, Y^p, for sale as an input to retailers is given as:

(64) $$Y^p = \sum_{i=1}^{4}\sum_{j=1}^{4}\alpha_{ij}\left(Z_i Z_j\right)^{\frac{1}{2}},$$

where Y^p is processed output. Z are total industry inputs of farm input (Y^f), labor (Z_1), capital (Z_2), and material (Z_3). From equation (64), the marginal product of the i^{th} input is:

(65) $$f_{Z_i} = \alpha_i Z_i + \sum_{j=1}^{4}\alpha_{ij}\left(\frac{Z_j}{Z_i}\right)^{\frac{1}{2}}.$$

Similarly, the marginal product of the k^{th} input in producing a retailer's output Y^r is derived as:

(66) $$f_{X_k} = \beta_k X_k + \sum_{h=1}^{4}\beta_{kh}\left(\frac{X_h}{X_i}\right)^{\frac{1}{2}}.$$

Normalized Quadratic (NQ) production function

The normalized quadratic (NQ) production function (Lau, 1978a, p. 194) is also commonly used due to its flexibility. The Normalized Quadratic is an attractive functional form for use in empirical applications as correct curvature can be imposed in a parsimonious way without losing the desirable property of flexibility. The NQ production function for the processor that uses a vector of inputs, Z, to produce a single output, Y^p, for sale as an input to retailers is given as:

(67) $$Y^p = \alpha_0 + \sum_{i=1}^{4}\alpha_i Z_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4}\alpha_{ij} Z_i Z_j,$$

where Z are total industry inputs of farm input, labor, capital, and materials, Y^p is the total processed industrial output of beef products. The NQ is symmetric in coefficients, i.e., $\alpha_{ij} = \alpha_{ji}$. From the above equation, the marginal product for the i^{th} input is

(68) $$f_{Z_i} = \left(\alpha_i + \sum_{j=1}^{4}\alpha_{ij} Z_j\right).$$

Similarly, the marginal product of the k^{th} input in producing a retailer's output Y^r is derived as:

(69) $$f_{X_k} = \left(\beta_i + \sum_{h=1}^{4} \beta_{kh} X_h\right).$$

Each system of equations is estimated jointly through Generalized Method of Moments (GMM)[6] technique (Hansen 1982) using the PROC MODEL Procedure in SAS.

Data

The data used in estimating the system of equations are monthly data series for the U.S. beef industry ranging from years 1980 to 2011. The data used in this study are compiled from the National Agricultural Statistic Service (NASS), Grain Inspection, Packers and Stockyards Administration (GIPSA), and the Economic Research Service (ERS) of the United State Department of Agriculture (USDA).

Total beef production represented by steer and heifer slaughter quantities is compiled from Livestock Slaughter Annual Summary of National Agricultural Statistics Service (NASS), United States Department of Agriculture (USDA). Total cattle input supply is represented by the cattle slaughter quantity in total live weight (NASS, USDA), and prices of labor, capital, and material inputs for the U.S. beef packing industry (NAICS code: 3116) are obtained from the Industry Productivity and Costs Database of Bureau of Labor Statistics (BLS), United States Department of Labor (USDL). The Herfindahl-Hirschman 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 (1996-2011), Grain Inspection, Packers and Stockyards

Administration (GIPSA), USDA. Prices series of wholesale and cattle is provided by ERS, USDA.

The total US commercial beef production which is used as the retail output obtained from red meat year book, Economic Research Service (ERS), United States Department of Agriculture (USDA). The prices of labor, capital, and food processing materials for the food processing industry are obtained from the Major Sector Multifactor Productivity Index Database of BLS (USDL). Retail Herfindhal-Hirschman Index (HHI) data are available only for years 1992, 1997, 2002, and 2007 which is estimated using sales data of the 50 largest grocery stores in the United States. Given the paucity of data, the Herfindhal-Hirschman Index data for the remaining years are estimated in time series regression. The retail sales data are obtained from several issues of the *Progressive Grocer Magazine* (Progressive Grocer, 1970-2002) and the U.S. Census Bureau. The retail price of beef is compiled from ERS, USDA.

For the beef supply equation and the processed beef supply equation, the productivity of labor, capital and the food processing materials are obtained from the *Major Sector Multifactor Productivity Index Database* (BLS, USDL). The productivity of labor, capital and materials for the U.S. animal slaughtering and processing industries are obtained from the *Industry Productivity and Cost Database* (BLS, USDL). The definitions and descriptive statistics of these variables are presented in Table II-1.

Empirical Results

Parameter estimates of the three cases of imperfect competition market structures with the Trans-log (TL) production function are reported in Table II-2. For the case of a single ‘processing/retailing’ sector, Case 1, all parameter estimates are statistically significant at the 5% level except α_{33}, parameter estimate of the average cost share of farm input. The estimated market power parameters are 0.0872 and 0.3022 which are significant at the 5% level. The statistical significance of these estimates evidences the existence of market power in both selling beef and procuring cattle markets. When the two-way bilateral imperfection is modeled, Case 2, all parameter estimates are statistically significant at the 5% significance level including estimates of market power parameters of processors’ oligopoly and retailers’ oligopsony, 0.0333 and 0.0272, respectively except α_{33}. The statistical significance of the market power estimates implies that there exists market power in both processors’ selling and retailers’ buying markets. However, degrees of market power estimated from the two-way model are significantly lower than those from the single sector case. In Case 3, all parameter estimates are statistically significant at the 5% level except β_{33} which implies constant capital share elasticity with respect to capital, estimates of processor oligopsony and retailer oligopoly power. Estimates of conjectural elasticities for output and input markets are 0.0866and 0.0162 for processors, and 0.0125 and 0.0420 for retailers. Therefore, results from the four-way model suggest that processors exert market power in selling beef while retailers exercise market power in procuring beef from processors. Processors’ oligopoly power is larger than other market power parameters.

Estimation results from the generalized Leontief production function (GL) are reported in Table II-3. In Case 1, all parameter estimates are significant at least at the 5% level. Estimates of conjectural elasticities for input and output markets are 0.1936 and 0.3078, respectively. The result suggests the existence of market power both in output and input market. In Case 2, all parameter estimates are significant at the 5% level. Estimates of market power parameters for processors' oligopoly and retailers' oligopsony are 0.0430 and 0.0143, respectively. The statistical significance of market power estimates indicate that there exists significant market power in both processed beef product output and procuring processed input markets. In Case 3, 21 of 24 estimated parameters are significant at the 5% level. However, retailers' oligopoly and olioposony power are not significant. Therefore, the statistical significance of estimates of market power parameters shows that the evidence of market power exertion of processor in both selling and buying markets.

Parameter estimates with the normalized quadratic (NQ) production function are reported in Table II-4. In Case 1, 16 of 17 parameter estimates are significant at the 5% significance level. The estimated market power parameters for output and input markets, 0.3419 and 0.2104 are significant at the 5% level. The statistical significance of these estimates evidences the existence of market power in both selling beef and procuring cattle markets. In Case 2, all parameter estimates are significant at the 5% significance level. The market power parameters estimates for output and input markets are 0.0398 and 0.0328, respectively. Both of them are significant at the 5% significance level. This implies that there exists market power exercise in both output and input markets. In Case 3, all parameter estimates are significant at the 5% level. Estimates of conjectural elasticities for output and input markets are 0.1481 and 0.0355 for processors, and 0.1478 and 0.1018 for retailers, respectively. The estimated elasticities are significant at the 5% level. Results from the four-way model suggest that retailers exercise market power in both selling beef and procuring processed beef, also processors exert market power in selling processed beef to retailers and procuring cattle input.

Estimated market power parameters from tables 2-4 are compared across alternative market structures and production functions and are reported in Table II-5. With the TL production function, the differences in conjectural elasticities between Case 3 and Case 1 are -0.0710 and -0.2602 for processors' oligopsony and retailers' oligopoly power, respectively, and are significant at the 5% level. The result suggests that a single 'processing/retailing' sector model with the TL production function tends to overestimate market power than the four-way model in both input and output markets. Comparing processors' oligopoly and retailers' oligopsony power between Cases 3 and 2 show only statistical difference in retailer oligopsony power. With the GL production function, the integrated single sector model, Case 1, also results in a larger estimate for processors' oligopsony power than the four-way model, Case 3, with the statistical significance at the 5% level. However, the retailers' oligopoly power shows no statistical difference between Cases 3 and 1. Comparing cases 3 and 2 shows that the two-way model with the GL production function shows no statistical difference.

With the NQ production function, the integrated single sector model, Case 1, also tend to overestimate processors' oligopsony power than the four-way model in input market. However, the retailers' oligopoly power shows no statistical difference between Case 3 and 1. Comparing cases 3 and 2 shows that the four-way model with the TL production function tends to overestimate market power than the two-way model in both input and output markets. Overall, estimates of market power parameters are sensitive to types of market structure models and functional forms of productions function. With production functions, the integrated model tends to overestimate market power parameters while the two-way model tends to underestimate them compared to the four-way model. No statistical difference is found when the TL and GL functions are used comparing the four-way model and the two-way model.

To compare overall market power exertion between processing and retail sectors, market power indices are estimated using parameter estimates reported in tables 2-4 and are reported in Table II-6. With the TL production function, market power indices in all three cases of market structures are significant at the 5% significance level except processor's market power index in Case 3. Comparing market power indices in Cases 3 and 1, retailers' market power index, 0.6714, in Case 1 is larger than that of four-way model, 0.2402. This result is statistically significant at 5% significance level. When market power indices are compared in cases 3 and 2, no statistical difference is found between processors' and retailers' market power. The results indicate that overall market power represented by market power indices is overestimated when market power is estimated using the integrated sector model with the TL production function. With the GL production function, all market power indices in processors and retailers are significant at the 5% level. Retailers' market power index from Case 1 is larger than those from cases 2 and 3, while processors' market power index from Case 2 is smaller than those from cases 1 and 3. Comparing market power indices in Cases 3 and 1, processors' market power index and retailers' market power index are 0.5634 and 0.6839, in case 1 are larger than those of four-way model, 0.0958 and 0.6763. When market power indices are compared in cases 3 and 2, market power indices for processor and retailer are larger in the four-way model than those of two-way model. However, only retailers' market power is statistically significant at the 5% level. When market power is estimated with the GL production function, the processor and retailer market power are overestimated from the integrated sector while the processor and retailer market power are underestimated from the two-way model. With the NQ production function, all market power indices are significant at the 5% significance level. Retailers' market power is only statistically difference between cases 3 and 1. However, differences in processors' and retailers' market power between cases 3 and 2 are statistically significant at the 5% level. The results indicate that the two-way model tends to underestimate the market power parameters and integrated as a single 'processing/retailing' sector model overestimate the market power parameters compared to the four-way model. Overall, the results show that estimates of market power indices are sensitive to types of market structure models and functional forms of productions function.

Conclusions

Most studies in the industrial organization literature have estimated potential market power effects in the U.S. beef industry. These studies assess market power effects of integrated retailer-processor industry while paying little attention to the retailers' potential market power. Recent studies consider bilateral relationship between processors and retailers and measure the potential market power effects from both sides of the markets. However, these studies have one limitation that conjectural elasticities are identical in output and input markets unless the production technology is restricted to be fixed proportion between input and output markets due to use of the dual cost function approach.

This paper considers bilateral imperfect competition between processors and retailers and employs the production function approach to measure the degree of market power in the U.S. beef industry. The production function approach allows deriving the conjectural elasticities without imposing the symmetry assumption in input and output markets. Using this framework, our study estimates conjectural elasticities of input and output markets for processors and retailers. After estimating conjectural elasticities from input and output markets, a market power index is derived and estimated to assess both selling and buying side of the degree of industry market power. Estimated market power parameters and market power indices are compared with those from two alternative market structures that have been widely used in previous studies and compared with three different types of production functions such as Trans-log, generalized Leontief and normalized quadratic functional forms to investigate the sensitivity of our results. Although estimates vary over alternative modeling approaches and functional forms of production function, overall results from the full-range, four-way model show the presence of market power exercise in both output and input markets between processors and retailers. In particular, when TL, GL, and NQ production functions are used in the NEIO specifications, the integrated model tends to overestimate market power parameters while the two-way model tends to underestimate them compared to the four-way model. When market power indices are constructed using the estimated market power parameters from different functional forms of production function, the direction of over- or under-estimation was found across alternative modeling approaches. One general conclusion is that estimates of market power are sensitive to types of market structure models and functional forms of productions function. Therefore, any erroneous choice of market structure model and functional form of production function could result in misleading estimates of market power.

Footnotes

1. This approach is similar to that developed by Lerner (1932), who defined the index of monopoly price distortions as the difference between the (output) price and marginal cost divided by the price.
2. Love and Shumway (1994), Azzamd and Pagoulatos (1990), and Sexton (2000) noted that market power estimates could be sensitive to selected functional form.
3. This bilateral oligopoly/oligopsony model is similar to the Schroeter's models (1988).
4. See Thompson (1988), Perroni and Rutherford (1996), and Diewert (2009).
5. Diewert flexibility or local flexibility implies that an approximating functional form conveys zero error (perfect approximation) for an arbitrary function and its first two derivatives at a particular point. Diewert's flexible functional form (FFF) requires that an FFF have parameter values such that the FFF and its first and second order derivatives are equal to the arbitrary function and its first and second order derivatives (Griffin, Montgomery, and Rister 1987; Thompson 1988).
6. GMM allows estimation under the restrictions implied by the theory; there is no need to add distributional assumptions that are not implied by the theory. GMM minimizes a weighted sum of the squared deviations, in which the weights reflect the variances and co-variances, and does not guarantee an efficient estimator, but it does provide a consistent estimator (Wooldridge 2001).

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Table II-1. Descriptive Statistics of Variables Used in the Empirical Estimation (1980.1-2011.12, N=384).

Variable	Symbol	Mean	SD	Minimum	Maximum
Herfindahl Hirschman index for steer and heifer slaughter	H^p	0.1646	0.0475	0.0561	0.2268
Herfindahl Hirschman index for grocery retailers	H^r	0.0397	0.0247	0.0081	0.0763
4 firm concentration ratio	C^s	71.5055	14.804	35.7	91.377
4 firm concentration ratio for grocery retailers	C^r	20.033	10.184	3.014	37.052
Commercial beef production (billion lbs.)	Y^r	2.0489	0.1825	1.653	2.512
Wholesale beef production (billion lbs.)	Y^p	2.7377	0.2218	2.2275	4.1485
Cattle slaughter weight (billion lbs.)	Y^f	3.4221	0.2772	2.7843	4.1485
Retail price of beef ($/cwt)	P^r	120.28	15.579	92.23	156.41
Wholesale value of beef ($/cwt)	P^p	80.058	3.248	73.926	92.314
Farm value of beef	P^f	69.280	1.299	62.843	74.899
Labor productivity for food and other industry (2005=100)	Y^r/Z_L	94.71	8.24	80.78	109.11
Capital productivity (2005=100)	Y^r/Z_C	102.78	2.909	96.54	107.48
Material productivity (2005=100)	Y^r/Z_M	86.04	13.43	67.10	106.19
Price of labor(2005=100)	V_L	109.07	4.361	100.00	119.73
Price of capital(2005=100)	V_C	125.91	13.24	97.06	148.91
Price of material(2005=100)	V_M	93.00	3.737	85.52	100.63
Labor productivity for animal slaughtering and processing(2005=100)	Y^p/X_L	97.97	8.659	83.57	112.85
Capital productivity (2005=100)	Y^p/X_C	101.98	1.974	97.43	105.61
Material productivity (2005=100)	Y^p/X_M	91.81	9.077	78.18	114.15
Price of labor(2005=100)	W_L	91.22	27.75	44.26	135.71
Price of capital(2005=100)	W_C	84.71	30.43	45.92	173.95
Price of material(2005=100)	W_M	102.97	22.222	70.50	158.22

Table II-2. Parameter Estimates of NEIO Models with Trans-log Production Function (N=384)

Parameters	Case 1		Case 2		Case 3	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
α_0	-1.3493**	0.1267	-0.3084**	0.0130	-0.3022**	0.0139
α_1	4.0829**	0.1708	1.1628**	0.0160	1.1606**	0.0086
α_2	0.3340**	0.0461	-0.0770**	0.0015	-0.0727**	0.0009
α_3	-0.0410**	0.0150	0.1140**	0.0041	0.1097**	0.0017
α_4	0.0552**	0.0081	-0.0426**	0.0014	-0.0399**	0.0063
α_{11}	-1.3947**	0.0656	-0.3895**	0.0161	-0.3827**	0.0070
α_{22}	0.0549**	0.0147	-0.0175**	0.0001	-0.0161**	0.0002
α_{33}	-0.0017	0.0026	0.0269**	0.0007	0.0257**	0.0001
α_{44}	-0.0571**	0.0079	-0.0030**	0.0001	-0.0035**	0.0014
α_{12}	0.2772**	0.0335	-0.0502**	0.0011	-0.0471**	0.0002
α_{13}	-0.0108**	0.0013	0.0103**	0.0003	0.0088**	0.0001
α_{14}	0.0488**	0.0074	-0.0312**	0.0007	-0.0310**	0.0002
α_{23}	-0.0025**	0.0006	0.0008**	0.0001	0.0004**	0.0001
α_{24}	0.0969**	0.0086	-0.0146**	0.0001	-0.0138**	0.0002
α_{34}	-0.0082**	0.0011	-0.0011**	0.0002	-0.0007**	0.0002
β_0			-1.2037**	0.0568	-1.3011 **	0.0404
β_1			3.9159**	0.0571	4.0870**	0.0517
β_2			0.0332**	0.0077	0.0408**	0.0064
β_3			-0.0561**	0.0033	-0.0537**	0.0028
β_4			0.2724**	0.0073	0.2695**	0.0134
β_{11}			-0.6161**	0.0321	-0.6750**	0.0204
β_{22}			0.0336**	0.0077	0. 0330**	0.0007
β_{33}			0.0007	0.0005	0.0006	0.0004
β_{44}			0.0643**	0.0005	0.0678**	0.0026
β_{12}			0.2745**	0.0068	0.2738**	0.0059
β_{13}			-0.0813**	0.0017	-0.0819**	0.0019
β_{14}			0.3060**	0.0075	0.3197**	0.0091
β_{23}			-0.0303**	0.0004	-0.0285**	0.0007
β_{24}			0.0658**	0.0005	0.0660**	0.0018
β_{34}			-0.0019**	0.0002	-0.0032**	0.0002
Ξ			0.0333**	0.0005	0.0866**	0.0375
Θ	0.0872**	0.0259			0.0162	0.0115
Φ	0.3022**	0.0928			0.0125	0.0215
Δ			0.0272**	0.0010	0.0420**	0.0092

** significant at the 5% significance level.
α_i: the average cost share of input *i* in processor sector.
α_{ij}: constant input *i's* share elasticity with respect to input *j*.
β_i: the average cost share of input *i* in retailer sector.
β_{ij} : constant input *i's* share elasticity with respect to input *j*.
Ξ, Θ: processors' oligopoly and oligopsony power parameter, respectively.
Φ, Δ: retailers' oligopoly and oligopsony power parameter, respectively.

Table II-3. Parameter Estimates of NEIO Models with Generalized Leontief Production Function (N=384)

	Case 1		Case 2		Case 3	
Parameters	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
α_{11}	0.7892**	0.0001	0.7650**	0.0001	0.7595**	0.0001
α_{22}	-0.6480**	0.0120	-1.7965**	0.0041	-2.0273**	0.0062
α_{33}	1.7502**	0.0305	4.4729**	0.0192	5.8177**	0.0074
α_{44}	0.4991**	0.0163	0.5620**	0.0039	0.2871**	0.0325
α_{12}	0.0528**	0.0005	0.1993**	0.0004	0.2524**	0.0001
α_{13}	-0.0018*	0.0010	0.0252**	0.0007	0.0045	0.0005
α_{14}	0.0688**	0.0006	0.2357**	0.0005	0.2999**	0.0012
α_{23}	0.0860**	0.0096	-0.4178**	0.0035	-0.7941**	0.0066
α_{24}	0.0387**	0.0129	-0.3925**	0.0039	-0.7527**	0.0099
α_{34}	-1.3160**	0.0149	-3.3593**	0.0051	-3.9010**	0.0054
β_{11}			0.7543**	0.0002	0.7553**	0.0007
β_{22}			0.3263**	0.0040	-0.0308**	0.0347
β_{33}			0.1375**	0.0072	0.9696**	0.0183
β_{44}			0.5386**	0.0021	0.2850**	0.0654
β_{12}			-0.0649**	0.0004	-0.0252**	0.0080
β_{13}			-0.0553**	0.0005	-0.0815**	0.0070
β_{14}			-0.1346**	0.0003	-0.1134**	0.0171
β_{23}			0.4088**	0.0036	-0.0572**	0.0513
β_{24}			1.1822**	0.0031	1.0587**	0.1541
β_{34}			1.2973**	0.0022	1.0705**	0.1646
Ξ			0.0430**	0.0002	0.0431**	0.0001
Θ	0.1936**	0.0095			0.0000**	0.0000
Φ	0.3078**	0.0042			0.2137	0.2180
Δ			0.0143**	0.0002	0.0934	0.0807

** significant at the 5% significance level.
α_{ij} and β_{ij} are the technology coefficients and implies substitutes effect between input *i* and *j*.
Ξ, Θ: processors' oligopoly and oligopsony power parameter, respectively.
Φ, Δ: retailers' oligopoly and oligopsony power parameter, respectively.

Table II- 4. Parameter Estimates of NEIO Models with Normalized Quadratic Production Function (N=384)

Parameters	Case 1 Coefficient	Case 1 Standard Error	Case 2 Coefficient	Case 2 Standard Error	Case 3 Coefficient	Case 3 Standard Error
α_0	-2.3270**	0.1098	-0.4550**	0.0108	-0.4427**	0.0186
α_1	2.1617**	0.0631	1.0490**	0.0103	1.0455**	0.0106
α_2	2.5266**	0.0895	7.4330**	0.0773	5.9918**	0.4202
α_3	-3.6547**	0.2578	-10.5122**	0.2111	-8.4864**	0.5938
α_4	1.4227**	0.0858	2.8298**	0.0711	2.2669**	0.1535
α_{11}	-0.3965**	0.0182	-0.0694**	0.0030	-0.0691**	0.0031
α_{22}	-77.4763**	2.0046	-228.834**	1.7427	-185.384**	12.786
α_{33}	484.766**	22.962	1371.51**	20.692	1107.52**	76.471
α_{44}	-16.8831**	2.1925	-55.0071**	1.3839	-44.5641**	3.1009
α_{12}	-0.1319**	0.0118	-0.1842**	0.0112	-0.1471**	0.0137
α_{13}	-0.10133**	0.0133	-0.1788**	0.0134	-0.1446**	0.0149
α_{14}	-0.1041**	0.0159	-0.0308**	0.0145	-0.0203**	0.0086
α_{23}	-39.3328**	4.5896	-188.027**	2.9290	-151.609**	11.032
α_{24}	-42.7686**	2.4146	-140.682**	2.2519	-112.923**	7.8498
α_{34}	4.2602	4.2476	50.4202**	4.4903	42.7619**	5.1135
β_0			-2.0315**	0.0677	-2.0052*	0.0677
β_1			2.0929**	0.0463	2.0854**	0.0463
β_2			4.0024**	0.0786	2.8006**	0.0619
β_3			5.1300**	0.0766	3.8923**	0.0520
β_4			-0.6919**	0.0470	0.3359**	0.0430
β_{11}			-0.4490**	0.0160	-0.4477**	0.0160
β_{22}			-150.23**	3.2081	-141.599**	2.9000
β_{33}			-248.641**	4.5571	-192.419**	2.9776
β_{44}			-2.6724**	0.8389	-21.0773**	0.8714
β_{12}			-0.2175**	0.0156	-0.1439**	0.0139
β_{13}			-0.4039**	0.0162	-0.3258**	0.0135
β_{14}			-0.2616**	0.0130	-0.1721**	0.0110
β_{23}			-198.444**	2.6250	-125.394**	1.7979
β_{24}			87.7300**	1.1660	85.1574**	1.1292
β_{34}			132.634**	1.5291	7.2948**	3.1218
Ξ			0.0328**	0.0004	0.1481**	0.0399
Θ	0.2104**	0.0014			0.0355**	0.0122
Φ	0.3419**	0.0004			0.1478**	0.0012
Δ			0.0398**	0.0012	0.1018**	0.0010

** significant at the 5% significance level.

Ξ, Θ: processors' oligopoly and oligopsony power parameter, respectively.

Φ, Δ: retailers' oligopoly and oligopsony power parameter, respectively.

Table II-5. Comparison of Estimated Market Power Parameters from Alternative Model Structures

	TL		GL		NQ	
Parameters	Case 3 vs. Case 1	Case 3 vs. Case 2	Case 3 vs. Case 1	Case 3 vs. Case 2	Case 3 vs. Case 1	Case 3 vs. Case 2
Ξ		0.0533		0.0001		0.1153**
		(0.0375)		(0.0004)		(0.0399)
Θ	-0.0710**		-0.1936**		-0.1749**	
	(0.0283)		(0.0095)		(0.0123)	
Φ	-0.2602**		-0.0941		-0.1941	
	(0.0933)		(0.1573)		(0.0013)	
Δ		0.0148**		0.0791		0.0620**
		(0.0093)		(0.0583)		(0.0016)

Notes: numbers in parentheses are standard errors.
** significant at the 5% significance level.
H_o: market power parameter (case 3)-Market power parameter (case 1 or case 2) =0.
H_a: market power parameter (case 3) -Market power parameter (case 1 or case 2) ≠0.
Ξ, Θ: processors' oligopoly and oligopsony power parameter, respectively.
Φ, Δ: retailers' oligopoly and oligopsony power parameter, respectively.

Table II-6. Comparison of Estimated Market Power Indices from Alternative Model Structures

Indices	Case 1	Case 2	Case 3	Case 3 Vs. Case 1	Case 3 Vs. Case 2
TL					
M^p	0.3677** (0.0690)	0.0740** (0.0011)	0.2712 (0.1257)	-0.0965 (0.1434)	0.1972 (0.1257)
M^r	0.6714** (0.2061)	0.1535** (0.0048)	0.2402** (0.0763)	-0.4312** (0.2061)	0.0867 (0.0738)
GL					
M^p	0.5634** (0.0054)	0.0957** (0.0005)	0.0958** (0.0007)	-0.4676** (0.0054)	0.0001 (0.0009)
M^r	0.6839** (0.0210)	0.0869** (0.0009)	0.6763** (0.2932)	-0.0076 (0.2934)	0.5894** (0.2932)
NQ					
M^p	0.5838** (0.0017)	0.0730** (0.0010)	0.4574** (0.1076)	-0.1264 (0.1076)	0.3844** (0. 0761)
M^r	0.7598** (0.0010)	0.2098** (0.0048)	0.6000** (0.0000)	-0.1598** (0.0010)	0.3902** (0.0048)

Notes: ** significant at the 5% significance level.
Numbers in parentheses are standard errors.
H_o: market power parameter (case 3)-Market power parameter (case 1 or case 2) =0.
H_a: market power parameter (case 3) -Market power parameter (case 1 or case 2) $\neq$0.
M^p: processors market power index. M^r: retailers market power index.

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