Estimating Market Power of Agricultural and Food Industries: An Issue of Data Aggregation

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Selected Poster prepared for presentation at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Joint Annual Meeting, San Francisco, CA, July 26-28

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Introduction

As agricultural and food industries become increasingly integrated and concentrated, there have been numerous studies estimating market power of these industries. New empirical industrial organization (NEIO) models first derive conceptual models from profit-maximizing-theory of a single "representative" firm, and then market power parameters are estimated using market- or industry-level data due to the lack of firm-level data. However, it is well known in empirical econometrics that when relations are derived from microeconomic theory, but are estimated by means of aggregated data, the aggregation can lead to biased parameter estimates.

Take the estimation of market power in the U.S. beef processing industry as an example. A conceptual model for this analysis may start from the theory of profit maximization and derive an individual processor's price equation with a market conduct parameter typically represented by a conjectural coefficient or elasticity of the processor. However, the empirical estimation of the model is usually based on aggregate time-series data at either market or industry level, which does not consider the heterogeneity of individual processor's firm behavior. The applied econometrics literature indicates that ignoring heterogeneity in estimates of individual firm behavior (represented by conjectural coefficient or elasticity) may result in biased estimation of overall market power of U.S. beef processors. Therefore, the issue of aggregation bias raises concerns regarding the validity of market power estimated from aggregate data and highlights the need for research designed to enhance our understanding of aggregation bias in estimating market power. A proper understanding of the aggregation problem and the particular method chosen for the resolution is of the crucial importance for estimating market power of agricultural and food industries.

Objectives

- This paper derives aggregation bias analytically from the previous NEIO approach. A statistical procedure is developed to quantify the degree of bias and conditions under which aggregation bias is likely to occur.
- New procedure is introduced to demonstrate how the aggregation bias can be reduced or eliminated by combining aggregated market-level data with published firm-level data.

Methodology

1. Traditional NEIO model

Let's suppose that cost function is a trans-log cost function form as

$$\log c = \beta_0 + \sum_{a=1}^{3}\beta_a \log w_a + \beta_y \log y + \frac{1}{2}\sum_{a=1}^{3}\sum_{b=1}^{3}\beta_{ab}\log w_a \log w_b + \sum_{a=1}^{3}\beta_{ya}\log y \log w_a + \beta_{yy}(\log y)^2 + v_i \qquad (1)$$

where $\beta_{nm}=\beta_{mn}$, w_n is input price, a,b= K, L, M, K is capital input, L is labor input, M is intermediate input and y is output.

The input demand function can be derived by Shephard's Lemma when cost is minimized under profit maximization problem.

$$s_a = \beta_a + \sum_{b=1}^{3}\beta_{ab}\log w_{ab} + \beta_{ya}\log y \qquad (2)$$

where $s_a = \frac{x_a w_a}{c}$, a= K, L, M and s_a is the industrial cost-share equation.

The equation (5) can be generated from the first order condition of profit maximization equation.

$$p = \left(\frac{c}{y}\right)\left[\beta_y + 2\beta_{yy}\log y + \beta_{y_K}\log w_K + \beta_{y_L}\log w_L + \beta_{yM}\log w_M\right]\Big/\left(1-\frac{\theta}{\eta}\right) \qquad (3)$$

where η is demand elasticity, c is total cost.

The equation (6) is output demand function and can be written as

$$\ln y = a + \eta \ln(p/S) + \rho \ln(q/S) \qquad (4)$$

where η is demand elasticity, ρ is income elasticity, q is GNP, S is GNP deflator.

The equation (7) is total cost

$$c = w_K x_K + w_L x_L + w_M x_M \qquad (5)$$

2. Aggregation Bias

- Aggregation Bias from Cost Share Equation

Let's assume that n firms exist, then sum each firm's cost share equation and divide by n, then the equation is expressed as

$$\frac{1}{n}\sum_{i=1}^{n}s_{ai} = \frac{1}{n}\sum_{i=1}^{n}\beta_{ai} + \frac{1}{n}\sum_{i=1}^{n}\sum_{b=1}^{3}\beta_{abi}\log w_{abi} + \frac{1}{n}\sum_{i=1}^{n}\beta_{yai}\log y_i \qquad (6)$$

Adding and subtracting $\sum_{b=1}^{3}\frac{1}{n}\sum_{i=1}^{n}\beta_{abi}\frac{1}{n}\sum_{i=1}^{n}\log w_{abi}$ and $\frac{1}{n}\sum_{i=1}^{n}\beta_{yai}\frac{1}{n}\sum_{i=1}^{n}\log y_i$, the equation (6) is

$$\bar{s}_a = \bar{\beta}_a + \sum_{b=1}^{3}\bar{\beta}_{ab}\log\bar{w}_{ab} + \bar{\beta}_{ya}\log\bar{y} + \sum_{b=1}^{3}\mathrm{cov}_i(\beta_{abi}, w_{abi}) + \mathrm{cov}(\beta_{yai}, \log y_i) \qquad (7)$$
$$-\frac{1}{2n}\sum_{b=1}^{3}\bar{\beta}_{ab}\sum_{i=1}^{n}(\log w_{abi} - \log\bar{w}_{ab}^{g})^2 - \frac{1}{2n}\bar{\beta}_{ya}\sum(\log y_i - \log\bar{y}_{ab}^{g})^2$$

- Aggregation Bias from Price Equation

The equation (3) can be showed as equation (8)

$$p = \left(\frac{c}{y}\right)\left\{\sum_{j=0}^{4}\beta_j \log\bar{x}_j\right\}\Big/\left\{1-\frac{\theta}{\eta}\right\} \qquad (8)$$

where i=1,2, …,n and $(\beta_{0i}, \beta_{1i}, \beta_{2i}\beta_{3i}, \beta_{4i}) = (\beta_{yi}, 2\beta_{yyi}, \beta_{y_{Ki}}, \beta_{y_{Li}}, \beta_{yMi}), (x_{0i}, x_{1i}, x_{2i}, x_{3i}, x_{4i}) = (1, y_i, w_{Ki}, w_{Li}, w_{Mi})$

Let's add and subtract $\sum_{j=0}^{4}\frac{1}{n}\sum_{i=1}^{n}\beta_{ji}\frac{1}{n}\sum_{i=1}^{n}\log x_{ji}$ to right sight and also $\frac{1}{\eta}\frac{1}{n}\sum_{i=1}^{n}\theta_i\frac{1}{n}\sum_{i=1}^{n}\frac{1}{k_i}$ to left side of equation (8),

$$p = \left(\frac{c}{y}\right)^h\left\{\sum_{j=0}^{4}\bar{\beta}_j\log\bar{x}_j + \sum_{j=0}^{4}\mathrm{cov}_i(\beta_{ji}, \log x_{ji}) - \frac{1}{2n}\sum_{j=0}^{4}\bar{\beta}_j\sum_{i=1}^{n}\left(\log x_{ji} - \log\bar{x}_j^{g}\right)^2\right\}\Big/\left\{1-\frac{\theta}{\eta}-\frac{1}{\eta}\mathrm{cov}\left(\theta_i, \frac{y_i}{c_i}\right)\cdot\left(\frac{c}{y}\right)^h\right\} \qquad (9)$$

where $\left(\frac{c}{y}\right)^h$ is the harmonic mean of $\frac{c_i}{y_i}$

- Theil(1971) derived an matrix equation that delineated aggregation bias form the linear model based on theoretical finding. We extend Theil's foundation to equation (9) and derive different kinds of aggregation bias.

$$Y = \bar{X}\bar{\beta} + \xi \qquad (10)$$

where $(x_{0i}, x_{1i}, x_{2i}, x_{3i}, x_{4i}, x_{5i}) = (1, y_i, w_{Ki}, w_{Li}, w_{Mi})$

$(\beta_{0i}, \beta_{1i}, \beta_{2i}\beta_{3i}, \beta_{4i}, \beta_{5i}) = (\beta_{yi}, 2\beta_{yyi}, \beta_{y_{Ki}}, \beta_{y_{Li}}, \beta_{yMi})$ $\xi = \frac{1}{n}\sum_{i=1}^{n}(\beta_i - \bar{\beta})(X_i - \bar{X}) - \frac{1}{2n}\sum_{i=1}^{n}S_{x,ig}^2\bar{\beta} + \varepsilon$

Y and ε are column vector with T-elements of $p_t\Big/\left(\frac{c}{y}\right)_t^h$ and ε_t, β_i and vector can be expressed as

$$\bar{\beta}' = [\bar{\beta}_0 \quad \bar{\beta}_1 \quad \bar{\beta}_2 \quad \bar{\beta}_3 \quad \bar{\beta}_4 \quad \bar{\theta}] = [\bar{\beta}_y \quad 2\bar{\beta}_{yy} \quad \bar{\beta}_{yK} \quad \bar{\beta}_{yL} \quad \bar{\beta}_{yM} \quad \bar{\theta}]$$
$$\beta_i' = [\beta_{0i} \quad \beta_{1i} \quad \beta_{2i} \quad \beta_{3i} \quad \beta_{4i} \quad \theta_i] = [\beta_{yi} \quad 2\beta_{yyi} \quad \beta_{yKi} \quad \beta_{yLi} \quad \beta_{yMi} \quad \theta_i]$$

From the equation (10),

$$\bar{b} = \bar{\beta} + \sum_{i=1}^{n}\left\{W_i - \frac{1}{n}I\right\}\beta_i - \sum_{i=1}^{n}R_i + \left(\bar{X}'\bar{X}\right)^{-1}\bar{X}'\varepsilon \qquad (11)$$

where $W_i = \left(\bar{X}'\bar{X}\right)^{-1}\bar{X}'\frac{1}{n}X_i, \sum_{i=1}^{n}W_i = I,\ R_i = \left(\bar{X}'\bar{X}\right)^{-1}\bar{X}'\frac{1}{2n}S_{x,ig}^2\bar{\beta}$

- The second term of right side of equation (11) is aggregation bias from ignoring the parameter heterogeneity and third term is the bias caused by using linearly aggregated data for nonlinear macro model.

Further Studies

- A new procedure that combines aggregate data and publicly available firm-level data will be developed to reduce aggregation bias.
- Empirical analysis will be conducted to demonstrate the aggregation bias and how the aggregation bias can be reduced by combining aggregate data and publicly available firm-level data in the newly developed procedure.

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