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A Stochastic Frontier Approach

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Introduction

Since the late 1980s, the analysis of market power in the food industries has shifted from analyzing market concentration (structure) towards empirically measuring how far a market diverges from perfect competition (conduct). The New Empirical Industrial Organization (NEIO; usually offspring of the work of Appelbaum, 1982, or Bresnahan, 1982) has dominated the food economics literature on market power in the past 25 years (see Kaiser and Suzuki, 2006, for a summary of NEIO applications to food industries) and continues to do so (Cakir and Balagtas, 2012; Hovhannisyan and Gould, 2012; Cleary and Lopez, 2014). NEIO studies, in general, find a significant degree of oligopoly power in the food industries (Bhuyan and Lopez, 1997; Lopez, Azzam and Liron, 2002; Sheldon and Sperling, 2003).

This study estimates mark-ups and oligopoly power for U.S. food industries using a stochastic frontier (SF; Kumbhakar, Baardsen and Lien, 2012; Baraigi and Azzam, 2014) approach, where mark-ups are treated as systematic deviations from a marginal cost pricing frontier. We apply the analysis to 36 U.S. food industries using NBER-CES Manufacturing Industry Database (2014), which covers a span of 31 years from 1979 to 2009. Empirical results show that all the food industries in the sample exercise at least some degree of oligopoly power, but most in a moderate manner. The estimated mean Lerner index is approximately 0.06, generally much lower than obtained using the conventional NEIO approaches. The SF model used provides a novel and promising framework to test and measure the degree of market power in agricultural and food markets.

The Stochastic Frontier Model

The SF estimator of market power was recently developed by Kumbhakar, Baardsen and Lien (2012). The model starts from the basic set-up of an industry exhibiting oligopoly, where the output price set exceeds marginal cost of production ($P > MC$). The gap between price and marginal cost is attributed to oligopoly power mark-up and is treated as a one-sided deviation. Thus, the model can be read as

$$P = MC + \Delta, where\, \Delta \geq 0. \tag{1}$$

Multiplying both sides of equation (1) by the output share in total cost $\frac{Y}{C}$, where Y is output and C is the cost of production, leads to the first-order condition for profit maximization

$$\frac{PY}{C} = \frac{\partial lnC}{\partial lnY} + \mu,\ where\ \ \mu \geq 0, \tag{2}$$

where the non-negative term μ captures the mark-up, which is zero for perfectly competitive behavior, and the larger it is, the greater the non-competitive mark-up is. To empirically estimate the mark-up we need data on revenue PY, cost, and the cost elasticity $\frac{\partial lnC}{\partial lnY}$.

Assume a cost function for the industry in question, $C = f(Y, W, T)$, where W is a vector of input prices and T is a trend variable to capture technical change. Using a standard translog cost function, the associated $\partial lnC/\partial lnY$ is as follows:

$$\frac{\partial lnC}{\partial lnY} = \ \beta_Y + \beta_{YY} lnY + \sum_{j=1}^{J} \beta_{jY} lnW_j + \beta_{YT} T\ . \tag{3}$$

Substituting (3) into (2) and imposing the homogeneity restriction of input prices ($\sum_{j=1}^{J} \beta_{jy} = 0$), the equilibrium condition is rewritten as

$$\frac{PY}{C} = \beta_Y + \beta_{YY} lnY + \sum_{j=1}^{J-1} \beta_{jy}\ ln\frac{W_j}{W_k} + \beta_{YT} T + \mu + \varepsilon, \tag{4}$$

where ε is a symmetric random disturbance accounting for noise, assumed to be independently and identically distributed with a mean of zero and variance σ_{ε}^{2}. The mark-up component μ is assumed to follow a half-sided normal distribution with variance σ_{μ}^{2} . The SF estimator of market power can be then obtained as $\hat{\mu}$.

Define the degree of market power as the fraction by which P exceeds MC, which is written as $\theta = (P - MC)/MC$. Then θ can be expressed as a function of the mark-up component μ. Using the estimated $\hat{\mu}$, $\hat{\theta}$ is obtained as

$$\hat{\theta} = \hat{\mu}/\frac{\widehat{\partial lnC}}{\partial lnY} \quad (5)$$

Estimates of the returns to scale *RTS* and the Lerner index $\mathcal{L}$ can be calculated as equations (6) and (7), respectively.

$$\widehat{RTS} = 1/\frac{\widehat{\partial lnC}}{\partial lnY} \quad (6)$$

$$\hat{\mathcal{L}} = \hat{\theta}/(1 + \hat{\theta}) \quad (7)$$

Data and Estimation

The SF model in equation (4) is estimated with panel data for 36 U.S. food manufacturing industries at the four digit Standard Industrial Classification System codes over annual observations for the 1979-2009 period. The main database used is the NBER-CES Manufacturing Industry Database (2014). Inputs are divided into four groups: materials (*M*), energy (*E*), labor (*L*) and capital (*K*). Capital was treated as a quasi-fixed input by including the annual user cost of capital services, which is calculated by

$$W_K = \gamma + \bar{d}, \quad (8)$$

where γ is the interest rate and $\bar{d}$ is the depreciation rate of capital. Assuming a 20-year equipment goodness in the food processing industry and a linear form, a value of 0.05 is applied to $\bar{d}$. All inputs are deflated to obtain approximations to physical quantities. Table 1 provides the variable definitions and the descriptive statistics of the sample.

Following Greene (2005a, b), we apply a “true” fixed-effects form to the SF model specified in equation (4), which allows us to disentangle time-invariant heterogeneity from time-varying inefficiency across the food industries under examination. The SF inefficiency estimator is obtained through Maximum Likelihood.

Results and Discussion

Table 2 presents estimates of the model parameters, mark-up component, degree of market power, returns to scale, and Lerner index. The estimated overall mean degree of market power is 6.4%, indicating that all the 36 food industries in the sample exercise at least some degree of oligopoly power, but most in a moderate manner. On average, industries under examination exhibit decreasing returns to scale, with the mean estimated as 0.6.

Table 3 lists the comparison panel of industry level Lerner index estimates and corresponding rankings between our analysis and those from Bhuyan and Lopez (1997, the summary study of the NEIO application to U.S. food industries). We find that using the SF approach, oligopoly power exerted by the U.S. food industries is much lower, albeit not competitive, than in previous studies using the NEIO methodology. Bhuyan and Lopez (1997) estimated the average Lerner index for the food industries at 0.33, about five times the degree in our study. Additionally, ranking of oligopoly power differs under the two mechanisms. Among all industries, the Ready to Eat Cereal industry exhibits a significant degree of oligopoly power under both NEIO and SF approaches, ranking the highest under NEIO and third under SF. Manufactured Ice ranks number one under SF but 15 with NEIO.

Meatpacking exhibits the lowest degree of market power in our model but sits in the middle under the NEIO estimates.

Compared to other studies, the food industry oligopoly power calculated from the SF model is generally much lower than that obtained using the conventional NEIO approaches. For instance, the average market power was estimated at 0.3 by Morrison (1990) and 0.1 by Hazilla (1991), higher than in of our study. Taking Meatpacking as another example, our Lerner index estimate of 0.06 is closer to Schroeter's (1988, estimated at 0.05) but much lower than other estimates such as by Azzam and Pagoulatos (1990, estimated at 0.46). The estimate for Roasted Coffee using SF is 0.05, whereas it was 0.06 in Roberts (1984). However, for the Fluid Milk industry, our estimate of 0.04 is slightly higher than the previous estimates done by Cakir and Balagtas (2012, estimated at 0.01) and Hovehannisyan and Gould (2012, estimated at 0.01). From a methodological standpoint, the SF function provides a promising framework to test and measure for the degree of market power, and its extension to assess market power determinants, following Battese and Coelli (1993), promises to be a worthwhile avenue of future research.

Table 1 Variable Description

Variable	Description	Mean	Std.dev	Min	Max
$\frac{PY}{C}$	Revenue Share of Cost	1.42	0.41	0.89	3.7
$Cost$	Total cost=cost of materials+ cost of energy + capital cost + wage ($MM)	7789.56	9793.07	155.19	67277.69
Y	Total output (MM)	8598.21	9617.34	226.55	53506.81
P_M	Price of materials	1.19	.25	.66	2.66
P_E	Price of Energy	1.23	.27	.52	2.25
P_K	Price of Variable Capital	.13	.03	0.1	.2
P_L	Wage rate in Hrs	14.3	5.16	4.04	29.62

Table 2 Estimation Results

		Coefficient	SEs	1st Quantile	Median	3rd Quantile
Model Parameter	β_{yy}	.165	.023***			
	β_{my}	.142	.044***			
	β_{ky}	-.227	.06***			
	β_{ly}	.106	.046**			
	β_{yT}	.001	.003			
Mark-up component $\hat{\mu}$		.105	.094	.06	.078	.11
Degree of market power $\hat{\theta}$		.064	.062	.035	.046	.068
Return to Scale $\widehat{RTS}$		.601	.077	.545	.587	.639
Lerner Index $\hat{\mathcal{L}}$		.058	.045	.034	.044	.063

Table 3 Market Power of the U.S. Food Industry

SIC	Industry	SFE	Rank	NEIO	Rank
2011	Meat packing plants	.037	36	.415	12
2013	Sausages and other prepared meats	.039	33	.21	26
2015	Poultry slaughtering and processing	.043	28	.392	13
2021	Creamery butter	.05	17	.5	9
2022	Cheese, natural and processed	.047	22	.254	20
2023	Dry, condensed, and evaporated dairy	.047	24	.593	4
2024	Ice cream and frozen desserts	.051	16	.332	16
2026	Fluid milk	.038	34	.236	22
2032	Canned specialties	.081	4	.116	32
2033	Canned fruits and vegetables	.042	32	.242	21
2034	Dehydrated fruits, vegetables, and soups	.053	15	.081	36
2035	Pickles, sauces, and salad dressings	.054	14	.53	6
2041	Flour and other grain mill products	.045	26	.679	2
2043	Cereal breakfast foods	.096	3	.717	1
2044	Rice milling	.056	11	.109	34
2047	Dog and cat food	.05	18	.115	33
2048	Prepared feeds, n.e.c.	.042	29	.448	11
2051	Bread, cake, and related products	.042	31	.219	24
2062	Cane sugar refining	.047	23	.33	17
2064	Candy and other confectionery products	.048	21	.16	29
2066	Chocolate and cocoa products	.055	12	.211	25
2067	Chewing gum	.062	8	.147	30
2074	Cottonseed oil mills	.055	13	.147	30
2075	Soybean oil mills	.042	30	.516	7
2076	Vegetable oil mills, n.e.c.	.06	10	.278	19
2077	Animal and marine fats and oils	.062	9	.296	18
2079	Edible fats and oils, n.e.c.	.049	19	.388	14
2082	Malt beverages	.075	7	.489	10
2084	Wines, brandy, and brandy spirits	.045	25	.228	23
2085	Distilled and blended liquors	.076	5	.571	5
2086	Bottled and canned soft drinks	.037	35	.595	3
2087	Flavoring extracts and syrups, n.e.c.	.013	2	.184	27
2092	Fresh or frozen prepared fish	.043	27	.092	35
2095	Roasted coffee	.048	20	.507	8
2097	Manufactured ice	.14	1	.38	15
2098	Macaroni and spaghetti	.075	6	.17	28
Mean		.06		.33	

Note: SFE: Stochastic Frontier Estimator

LI: Lerner Index

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