International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2017, 7(4), 645-649.

# Functional Forms and Oligopolistic Models: An Empirical Analysis

**David Bouras[1]*, Troy Frank[2], Eric Burgess[3]**

[1]School of Business, Lincoln University, USA, [2]School of Business, Lincoln University, USA, [3]School of Business, Lincoln University, USA. *Email: bourasd@lincolnu.edu

**ABSTRACT**

This paper attempts to empirically test the sensitivity of the New Empirical Industrial Organization (NEIO) approach to the assumed demand and cost functional forms. Such an approach relies upon oligopolistic models to infer the degree of competition in a market. Unlike prior studies (Genesove and Mullin, 1998; Clay and Troesken, 2003), this paper focuses on the effect of the assumed cost function on the assessment of market power. Using data from the US catfish industry, the empirical results reveal that the NEIO approach is fairly robust to the assumed demand and cost functional forms.

**Keywords:** Demand, Cost, New Empirical Industrial Organization, Market Power
**JEL Classifications:** C51, D24, D40

## 1. INTRODUCTION

The bulwark of the "New Empirical Industrial Organization" method (NEIO, hereafter) is the relation linking the equilibrium price to marginal cost (e.g., Bresnahan, 1982; Genesove and Mullin, 1998); that is,

$$P = MC - \theta Q\left[\frac{dP}{dQ}\right], \qquad (1)$$

Where, P, Q, and MC, are, respectively, output price, industry output, and marginal cost; and $\theta$ is an index of market power capturing various market structures. These include, among others, perfect competition when θ is equal to zero; monopoly power when θ is equal to one; and oligopoly power when θ lies between zero and one.

Inferring the degree of competition using equation (1) can be problematic, however. Cost information and demand parameters are not readily available. Hence, empirical estimations appear to be the only way of obtaining the needed cost and demand information. The empirical estimations of the parameters of the cost and demand functions, however, require the selection of functional forms. Such a task can be tedious due to lack of theoretical and empirical foundations regarding the choice of appropriate functional forms. This, in turn, prompted economists to question the robustness of NEIO technique to the choice of the demand functional form. In that context, two studies attempted to evaluate empirically the robustness of the NEIO method: One in the sugar industry by Genesove and Mullin (1998), and the other in the whisky industry by Clay and Troesken (2003). These two studies used the adjusted Lerner index (ALI) as a benchmark and found that the NEIO approach is robust to the assumed demand functional form, especially for small values of the conduct parameter[1]. Whether the NEIO technique is robust to the assumed cost functional form is an open question that needs to be addressed.

In that setting, this paper fills the gap in the extant literature by testing empirically the sensitivity of the NEIO approach to the assumed cost functional form. It also contributes to the existing literature that examined competition in the US catfish industry in two different ways[2]. First, it addresses the sensitivity of the NEIO methodology to the selection of the cost and demand functional forms. Second, one of the pitfalls of the research papers that investigated competition in the US catfish industry is their assumption that catfish processors sell a homogeneous product. In reality, however, catfish processing plants sell different forms

1 The ALI is given by: $\theta = \eta\left[\frac{P - MC}{P}\right]$, where η is the elasticity of demand; and θ is the ALI or the conduct parameter.

2 A substantial body of literature looked at competition in the US catfish industry (e.g., Kinnucan and Sullivan, 1986; Kouka, 1995; Bouras and Engle, 2007; Bouras et al., 2010). These studies, however, relied upon a simple functional form for the demand and cost functions.

of processed catfish, including primarily fresh and frozen whole catfish, fillet, nuggets, and steak. To address this issue, we focus exclusively on fresh whole dressed catfish.

The paper is organized as follows: The first section provides the conceptual model; the second section contains data and the estimation of the econometric models; the third section reports comparative analyses; the last section concludes the paper.

## 2. CONCEPTUAL MODEL

The starting point of our conceptual model is a catfish processor that converts live catfish into, among others, fresh whole dressed catfish. In that setting, the profit of producing and selling fresh whole dressed catfish can be formulated as:

$$\pi_i = P(Q) \times q_i - TC \qquad (2)$$

Where, $\pi_i$ is the profit of the i$^{th}$ processor; P and $q_i$ are, respectively, the price and quantity sold of fresh whole dressed catfish; and TC is the total cost of producing fresh whole dressed catfish, which includes the processing cost and the cost of live catfish. The first-order condition can be expressed as:

$$\frac{d\pi_i}{dq_i} = 0 \implies P + q_i \frac{dP}{dQ}\frac{dQ}{dq_i} - MC = 0 \qquad (3)$$

After a few algebraic manipulations, equation (3) can be re-written as:

$$P = MC - Q\frac{dP}{dQ}\theta, \qquad (4)$$

Where $\theta = \left[\frac{dQ}{dq_i}\frac{q_i}{Q}\right]$ is a measure of market power (Iwata, 1974; Bresnahan, 1982; Lau, 1982). Inferring θ from equation (4) requires the estimation of the parameters of the cost and demand functions. To this end, on the demand side, we use the following demand functional form (e.g., Genesove and Mullin, 1998):

$$Q(P) = \beta(\alpha - P)^{\gamma} \qquad (5)$$

Where, Q is the quantity sold of fresh whole dressed catfish; and P is the price of fresh whole dressed catfish. We choose the above functional form because it encompasses several forms, including, among others, the log-linear form ($\alpha = 0$ and $\gamma < 0$) and the linear form ($\gamma = 1$). For empirical application, we focus on the most commonly used functional forms, that is, the linear and log-linear forms. These functional forms are, respectively, given by:

$$\text{Linear: } Q = \beta(\alpha - P) + \mu, \qquad (6)$$

$$\text{Log-linear: } \ln(Q) = \ln(-\beta) + \gamma \ln(P) + \mu \qquad (7)$$

Using the demand function given in equation (5), equation (4), after a few algebraic manipulations, takes the following final form:

$$P = \left[\frac{\alpha\theta}{\gamma + \theta}\right] + \left[\frac{\gamma}{\gamma + \theta}\right] MC \cdot \qquad (8)$$

Equation (8) is termed the generalized pricing rule function (for example, Genesove and Mullin, 1998).

On the cost side, we decompose marginal cost into two major components: Marginal processing cost and the cost of live catfish. It is known that live catfish is converted in fixed and known proportions into fresh whole dressed catfish. Hence, marginal cost can be formally expressed as:

$$MC = mpc + k \times W \qquad (9)$$

Where, mpc is marginal processing cost; k is the conversion factor; and W is the price of live catfish.

The estimation of marginal cost as given in equation (9) requires knowledge of mpc and k. While the value of the conversion factor, k, can be obtained from extraneous information, the estimation of marginal processing cost, mpc, can be tedious. In the existing NEIO literature, the estimation of marginal processing cost is based on the selection and estimation of a specific functional form. In this paper, and in order to test the sensitivity of NEIO methodology to the selection of the cost functional form, we use three different methods. These methods include: The Generalized Leontief form, the linear form, and the Genoseve and Mullin's technique (1998). The Generalized Leontief marginal processing cost (e.g., Appelbaum, 1982) is given by:

$$mpc = \sum_{i=1}\sum_{j=1}\delta_{ij}\left(p_i p_j\right)^{1/2}, \qquad (10)$$

Where, p is a vector of input prices. As in Bouras and Engle (2007), we use three input prices: Labor ($p_L$), capital ($p_K$), and energy ($p_E$). Marginal processing cost as given in equation (10) becomes

$$mpc = \delta_{EE}p_E + \delta_{KK}p_K + \delta_{LL}p_L + 2\delta_{EK}(p_E p_K)^{½} + 2\delta_{EL}(p_E p_L)^{½} + 2\delta_{KL}(p_E p_L)^{½} \qquad (11)$$

The linear marginal processing cost (e.g., Corts, 1999), on the other hand, can be formulated as:

$$mpc = \varphi_0 + \sum_{i=1}\varphi_i p_i \,. \qquad (12)$$

Using the input prices, as previously defined, the linear marginal processing cost becomes:

$$mpc = \varphi_0 + \varphi_E p_E + \varphi_K p_K + \varphi_L p_L \qquad (13)$$

Finally, the Genesove and Mullin's technique (1998) consists of treating marginal processing cost as a parameter and then estimating it along with other model's parameters. Specifically, marginal cost can be expressed as:

$$MC = mpc + k \times W \qquad (14)$$

Where, MC is marginal cost; mpc is a parameter representing marginal processing cost; k is the conversion factor; and W is the price of live catfish.

## 3. DATA AND ESTIMATION PROCEDURE

The econometric models include two different demand functional forms, including the log-linear and linear forms; and three

**Table 1: Summary statistics**

| Variable | Minimum | Maximum | Mean±SD |
|---|---|---|---|
| Price of live catfish ($/Lb) | 0.55 | 0.80 | 0.70±0.08 |
| Price of fresh whole dressed catfish ($/Lb) | 1.43 | 1.89 | 1.72±0.14 |
| Quantity sold of fresh whole dressed catfish (1000 Lbs) | 5851.00 | 9955.00 | 7520.14±855.17 |
| Bank loan rate (%) | 4.00 | 9.50 | 6.98±1.78 |
| Electricity price (¢/kWh) | 4.26 | 5.56 | 4.77±0.31 |
| Hourly minimum wage ($/h) | 4.25 | 5.15 | 4.80±0.42 |

SD: Standard deviation

**Table 2: Nonlinear estimates of demand functions**

| Parameter | Demand functional form | |
|---|---|---|
| | Linear | Log-linear |
| α or ln(−β) | 5.03* (1.602) | 9.17* (0.134) |
| β or γ | 2268.74* (1118.571) | −0.47** (0.232) |
| Demand elasticity (η) | −0.52* (0.256) | −0.47** (0.232) |
| $R^2$ (%) | 13.80 | 12.60 |
| Log-likelihood | −412.39 | 42.88 |
| Number of observations | 51 | 51 |

Standard errors are between parentheses. *,**, and *** represent 1%, 5%, and 10% significance level, respectively

generalized pricing rule functions. These pricing rule functions are obtained by using three different cost functions, including the linear and generalized Leontief forms, and the Genesove and Mullin's technique. To empirically estimate the econometric models, we use quarterly data ranging from 1992:II to 2004:IV. The data were collected from various sources. The price of live catfish, and the quantity sold and price of fresh whole dressed catfish were collected from the United States Department of Agriculture; hourly minimum wage was obtained from the United States Department of Labor; average retail electricity price was taken from the United States Department of Energy; and the bank loan rates were compiled from the Federal Reserve Bank of St. Louis. Summary statistics are reported in the Table 1.

To estimate the demand functions, we use the non-linear least squares method. Heteroskedasticity and autocorrelation-consistent standard errors are computed using the Newey and West's technique (1987). Table 2 contains the estimates of the parameters of the log-linear and linear demand functions. Also reported in Table 2 are the estimates for the demand elasticities (η) for the log-linear and linear demand functions[3].

Having estimated the parameters of the demand functions, the next step is to use them along with an estimate of k, the conversion factor, to estimate the parameters of the generalized pricing rule functions. Our estimate of k is taken from Silva and Dean's study (2001). According to that study, one pound of live catfish yields 0.62 pounds of fresh whole dressed catfish; that is, for every pound of fresh whole dressed catfish produced 1.61 pounds of live catfish will be required. So, the value of k is 1.61.

The estimates of the parameters of the generalized pricing rule functions are presented in Table 3. Of paramount relevance is the index of market power, θ. A casual look at the results shows that the point estimates of θ are close to zero. More importantly, and in most cases, the null hypothesis that θ is equal to zero cannot be rejected, implying that the market for fresh whole dressed catfish is competitive. The empirical results, therefore, suggest that the NEIO methodology is fairly robust to the assumed demand and cost functional forms.

3 The elasticity of demand for the linear form is computed at the mean values for the quantity and price of fresh whole dressed catfish.

## 4. COMPARATIVE ANALYSES

In this section, we compare our estimate for market power; i.e. θ, obtained previously using the NEIO technique with a benchmark for market power. Our benchmark for market power is obtained by using the ALI. This index is given by:

$$ALI = \eta\left[\frac{P - MC}{P}\right], \quad (15)$$

Where, P is the price of fresh whole dressed catfish; η is the elasticity of demand for fresh whole dressed catfish; and MC is marginal cost. Substituting (14) into (15) results in:

$$ALI = \eta\left[\frac{P - mpc - k \times W}{P}\right], \quad (16)$$

Where, mpc is marginal processing cost; k is the conversion factor; and W is the price of live catfish.

To compute the ALI, we use our previous estimates for the elasticities of demand for fresh whole dressed catfish, η, for the log-linear and linear demand functions; the price of live catfish; the price of fresh whole dressed catfish; and an estimate for marginal processing cost (mpc). Our proxy for marginal processing cost comes from a study by Lazur (1997). Following that study, the cost of processing one pound of live catfish into fresh whole dressed catfish is $0.44. So, the value of mpc is 0.44. Yearly estimates of adjusted Lerner indices are provided in Table 4 and Figure 1. The average values of the adjusted Lerner indices are 0.040 and 0.046 for the log-linear and linear demand functional forms, respectively. These estimates are close to zero suggesting, once again, that the market for fresh whole dressed catfish is competitive. In addition, the estimates of the adjusted Lerner indices are, to a greater extent, similar to those of the index of market power, θ, obtained previously using the NEIO methodology.

It is also interesting to compare our proxy for marginal processing cost with the estimates for marginal processing cost obtained previously using the Genesove and Mullin's technique (1998). Table 5 contains the 99% confidence interval for marginal processing cost estimated using the Genesove and Mullin's

**Table 3: Nonlinear estimates of generalized pricing rule functions**

| Parameter | Demand specification | | | | | |
|---|---|---|---|---|---|---|
| | Linear form | | | Log-linear form | | |
| | Cost specification | | | Cost specification | | |
| | GLF | LF | GMT | GLF | LF | GMT |
| | Estimate | | | Estimate | | |
| $\varphi_0$ or mpc | | −0.02 | 0.69* | | −0.58* | 0.54* |
| | | (0.391) | (0.088) | | (0.164) | (0.046) |
| θ | −0.10* | −0.11 | −0.03 | 0.01 | 0.05 | 0.01 |
| | (0.037) | (0.093) | (0.026) | (0.021) | (0.044) | (0.012) |
| $\varphi_E$ or $\delta_{EE}$ | −0.61 | 0.10* | | −0.10 | 0.10* | |
| | (0.423) | (0.019) | | (0.424) | (0.019) | |
| $\varphi_K$ or $\delta_{KK}$ | 0.08 | 0.01** | | 0.13* | 0.01** | |
| | (0.063) | (0.006) | | (0.044) | (0.006) | |
| $\varphi_L$ or $\delta_{LL}$ | −0.46 | 0.09* | | −1.14** | 0.09* | |
| | (0.380) | (0.021) | | (0.512) | (0.021) | |
| $\delta_{EK}$ | 0.02 | | | −0.13** | | |
| | (0.061) | | | (0.049) | | |
| $\delta_{EL}$ | 0.67*** | | | 1.19** | | |
| | (0.372) | | | (0.446) | | |
| $\delta_{KL}$ | −010* | | | 0.003 | | |
| | (0.031) | | | (0.065) | | |
| $R^2$ (%) | 95.14 | 93.84 | 82.86 | 93.88 | 93.84 | 82.86 |
| Log-likelihood | 105.55 | 99.47 | 73.38 | 99.63 | 99.47 | 73.38 |
| Number of observations | 51 | 51 | 51 | 51 | 51 | 51 |

Standard errors are between parentheses. These are computed using the Newey and West's technique (1987); GLF: Generalized Leontief form, LF: Linear form, GMT: Genesove and Mullin's technique, *,**, and *** represent 1%, 5%, and 10% significance level, respectively

**Table 4: Yearly estimates of ALI**

| Year | ALI | |
|---|---|---|
| | Mean±SD | |
| | Linear demand | Log-linear demand |
| 1992 | 0.013±0.009 | 0.017±0.011 |
| 1993 | 0.014±0.006 | 0.014±0.005 |
| 1994 | 0.038±0.010 | 0.033±0.006 |
| 1995 | 0.042±0.005 | 0.035±0.004 |
| 1996 | 0.050±0.012 | 0.041±0.006 |
| 1997 | 0.048±0.004 | 0.042±0.004 |
| 1998 | 0.043±0.009 | 0.038±0.006 |
| 1999 | 0.046±0.011 | 0.040±0.008 |
| 2000 | 0.070±0.022 | 0.055±0.014 |
| 2001 | 0.069±0.005 | 0.063±0.004 |
| 2002 | 0.034±0.002 | 0.037±0.005 |
| 2003 | 0.051±0.016 | 0.049±0.009 |
| 2004 | 0.081±0.013 | 0.058±0.006 |
| Average | 0.046±0.010 | 0.040±0.007 |

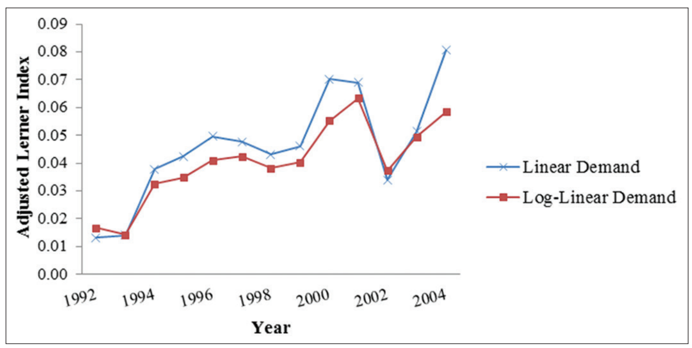
SD: Standard deviation, ALI: Adjusted Lerner index

**Table 5: Marginal processing cost: Direct measure versus Genesove and Mullin's technique**

| Direct measure | 99% confidence interval for marginal processing cost/Genesove and Mullin's technique | | | |
|---|---|---|---|---|
| | Linear demand | | Log-linear demand | |
| | Lower bound | Upper bound | Lower bound | Upper bound |
| 0.44 | 0.45 | 0.92 | 0.42 | 0.66 |

technique (1998) along with the direct measure of marginal processing cost taken from Lazur's study (1997). The estimates of marginal processing cost using the Genesove and Mullin's technique (1998) range from \$0.42/Lb to \$0.66/Lb for the log-linear demand function; and range from \$0.45/Lb to \$0.92/Lb for the linear demand function. It should be pointed out that the Genesove and Mullin's technique (1998) performed relatively well, especially when using the parameters taken from the log-linear demand function.

**Figure 1:** Yearly estimates of adjusted lerner indices




## 5. CONCLUSION

This paper attempts to empirically test the sensitivity of the NEIO technique to the assumed demand and cost functional forms. The focus of the paper is, however, on the effect of the assumed cost function on the estimation of market power. Using data from the US catfish industry, our empirical results reveal that the New Empirical Industrial Organization approach is fairly robust to the assumed demand and cost functional forms. In addition, the empirical results indicate that the Genesove and Mullin's technique for estimating marginal processing cost performed relatively well particularly when using the parameters taken from the log-linear demand function.

## REFERENCES


Appelbaum, E. (1982), The estimation of the degree of oligopoly power. Journal of Econometrics, 19, 287-299.

Bouras, D., Engle, C. (2007), Assessing oligopoly and oligopsony power in the US catfish industry. Journal of Agribusiness, 25(1), 47-57.

Bouras, D., Kaliba, A., Bouras, A., Dutta, A. (2010), Testing for market power in the U.S. Catfish processing industry: A dynamic error correction approach. Journal of Applied Economics and Policy, 29, 15-33.

Bresnahan, T. (1982), The oligopoly solution is identified. Economics Letters, 10, 87-92.

Clay, K., Troesken, W. (2003), Further tests of static oligopoly models: Whiskey, 1882-1898. Journal of Industrial Economics, 51(2), 151-166.

Corts, K.S. (1999), Conduct parameters and the measurement of market power. Journal of Econometrics, 88, 227-250.

Genesove, D., Mullin, W.P. (1998), Testing static oligopoly models: Conduct and cost in the sugar industry 1890-1914. Rand Journal of Economics, 29, 355-77.

Board of Governors of the Federal Reserve System. (1992-2004), Bank Prime Loan Rate, Federal Reserve Bank of St. Louis. Available from: https://www.fred.stlouisfed.org/series/MPRIME.

Iwata, G. (1974), Measurement of conjectural variations in oligopoly. Econometrica, 42, 947-966.

Kinnucan, H., Sullivan, G. (1986), Monopsonistic food processing and farm prices: The case of the West Alabama catfish industry. Southern Journal of Agricultural Economics, 18, 15-24.

Kouka, P. (1995), An empirical model of pricing in the catfish industry. Marine Resource Economics, 10, 161-169.

Lau, L.J. (1982), On identifying the degree of competitiveness from industry price and output data. Economic Letters, 10, 93-99.

Lazur, A.M. (1997), Small Scale, On-Farm Fish Processing. Southern Regional Aquaculture Center Publication, No. 442.

Newey, W., West, K. (1987), A simple, positive semi-definite, heteroscedastic and auto correlation consistent covariance matrix. Econometrica, 55, 703-708.

Silva, J.L., Dean, S. (2001), Processed Catfish: Product Forms, Packaging, Yields and Product Mix, Southern Regional Aquaculture Center Publication, No. 184.

U.S. Department of Agriculture, Catfish and Trout Production. National Agricultural Statistics Service. (1992-2004).

U.S. Department of Energy, Energy Information Administration. Monthly Energy Review. (1992-2004).

U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings. (1992-2004).