Testing for Market Power and Welfare Effects in the US Catfish Industry

Abstract

An empirical specification of the conjectural variations model, which conforms to microeconomic theory and has no specification errors, is estimated in the US catfish industry. We find the existence of market power in catfish processing sector. Processors force price paid to catfish growers down by 12% to 37%, and it costs the US catfish growers at least $52 million/year. The catfish growers can deter negative effects of market power by increasing farm supply flexibility. Further studies are needed to address the dynamics issue, competitive game strategies in the US catfish industry.

Key Words: *US catfish, market power, welfare distribution, policy implication*

JEL classification: L11, L13, D43.

Introduction

Catfish production is the largest US aquaculture component. The industry has contributed significantly to local economies, especially in the southern states of the US (Hanson et al, 2004). The industry enjoyed a long period of growth from 1970s to early 2000s (Hanson and Sites, 2010). Since 2003, the industry has been experiencing reductions in production acres, output, and sale values, and losing its market share from 91% in 2005 to 62.7% in 2010 (USDA, 2011). Recent literature accuses the competition of catfish-like imports (Quagrainie, 2006; Lee and Kennedy, 2009), and high prices of feed and fuel (Byrd, 2008) to be the reason for the decline in the US catfish industry. None of the recent studies looked at the market structure as a potential cause for the decline in the US farm-raised catfish competitiveness.

An imperfect market structure has long been suspected in the US catfish processing sector. The sector is highly concentrated with a four-firm concentration ratio of 60-70% in the early 1990s (Dillard, 1995), and 52% in the early 2000s (Masuda, 2002). The number of processors is relatively small compared to the number of catfish growers; the number reached the highest of 37 in 1990, and decreased to about 20 processors lately, mainly located in the Mississippi delta region where more than 90% of catfish sold are produced (Bouras et al, 2010). Farm-raised catfish are delivered live to processing plants to maintain the quality and freshness, and are processed shortly after arrival to the plants. Processors may have a certain degree of market power over catfish growers within the neighboring areas where the distance play a role in maintaining the quality of live catfish deliveries. The industry structure aroused concerns about potential market power imposed by processors at the farm level and wholesale markets, because the market power of catfish processing sector will erode the profit of catfish growers.

Studies of market power in the US catfish industry, however, show mixed results. Kinnucan and Sullivan (1986) analyzed a case of pure monopsony, which was common to the catfish processing in West Alabama in the early 1980s, and estimated a potential reduction of 12%-35% in price received by catfish growers resulted from the monopsonistic processing sector. Kouka (1995) suspected oligopoly power of US catfish processing, and found conjectural variations elasticity of 0.52, and oligopoly power index of 0.44. Kouka (1995) conluded that there is some degree of price enhancement in the wholesale/retail market of processed catfish products. In contrast, in their recent studies, Bouras and Engle (2007) and Bouras et al (2010) employed the conjectural variations model to test for market power in the US catfish processing sector. The authors used annual or quarterly aggregate data of the period 1987-2003/2004, and did not find any statistically significant evidence of oligopoly and oligopsony power in the US catfish processing industry.

The conjectural variations model is most often used to test for market power in a specific industry or products (Digal and Ahmadi-Esfahani, 2002). It is also the case for the US catfish industry as in Kouka (1995), Bouras and Engle (2007), and Bouras et al (2010). However, the conjectural variations model is difficult to implement due to extensive data requirements and sensitivity to specification errors (Hyde and Perloff, 1995). Hence, it is difficult to determine whether the estimates of market power in the conjectural variations model are reliable because they may be the results of imposed market structure, or measurement and misspecification errors (Azzam and Anderson, 1996). Therefore, the mixed results in the previous tests of market power in the US catfish industry may originate from different empirical functional forms and misspecification errors, for which none of the previous studies tested (Kouka 1995, Bouras and Engle 2007, and Bouras et al 2010). In addition, the conjectural variations model has a limitation that it relies on several basic assumptions which were not tested in the previous studies, e.g. fixed proportion processing technology (Kouka 1995, Bouras and Engle 2007, and Bouras et al 2010).

The current study will make additional contributions, compared to the previous studies of market power in the US catfish processing sector, in following areas: First, this study surveys different empirical specifications, and conducts tests of specification error of the empirical models; Second, the study conducts the tests of several basic assumptions of the conjectural variations model, such as fixed proportion, and constant-returns-to-scale technology; Third, this study uses monthly data to increase the number of observations and the robustness of the empirical estimation; Finally, the study evaluates the welfare effects of market power on farm and wholesale prices, and discusses policy implications for the US catfish industry. The rest of the paper is organized as follows: Model Development, Empirical Specification and Estimations, Welfare Effects and Policy Discussion, and Conclusions.

Model Development

There are four general approaches used to analyze market power: the industry case study approach; the structure-conduct-performance (SCP) approach; the new empirical industrial organization (NEIO) approach; and the time-series analysis of prices in vertically-related markets. The NEIO approach has the strongest microeconomic foundation. The NEIO approach focuses on aspects of market conduct such as behavior and strategic reactions of firms in the industry. There are several models which are widely used in the NEIO approach, such as estimation of marginal cost, conjectural variations models, and comparative statics models. The conjectural variations models appear to be the ‘workhorse’ model (Digal and Ahmadi-Esfahani, 2002). A firm believes that its rivals react to its output choices, called a conjectural variation (Azzam and Pagoulatos, 1990). The conjectural variations model is suitable for application to a specific product or industry, and often applied in food processing sectors.

The NEIO approach, however, has some limitations because it relies on several assumptions of market conduct and structure. First, the approach assumes a fixed proportion technology; second, it assumes that firms have equal market shares, and equal conjectural variations in equilibrium, and restricted entry. Due to the lack of data at the firm level, most studies have to aggregate data for theentire industry, hence the Gorman polar cost function, which assumes that firms have different fixed costs (intercepts), but identical marginal costs (slopes) is often used in conjectural variations model; Third, the conjectural variations models are sensitive to choices of functional forms. The model would be only powerful if it is correctly specified (Hyde and Perloff, 1995), and it requires an extensive experimentation of specifications. The full system estimation approach appears to be the best option to address this problem; Fourth, the conjectural variations models assume a priori modes of market conduct and structure such as oligopolistic (Cournot vs. Bertrand) or monopolistic and collusion. Hence, it is unknown whether the gap between marginal cost and price is due to the assumptions on market structures or due to measurement and misspecification errors. Azzam (1992) dealt with the problem by developing a model to test for the equality of marginal cost and price; Finally, the conjectural variations models engage a dynamic behavior of rival firms reaction to output choices of a firm, but actually the derived model is a static framework.

This study employs a model developed by Schroeter (1988) to link the farm price and the wholesale price in the presence of oligopoly and oligopsony power. The wholesale demand for

US processed catfish depends on wholesale prices, and demand shifters. The inverse demand function is:

$$P_w = D(Q_w, \mathbf{Z}) \qquad (1)$$

where, P_w is wholesale price, Q_w is wholesale volume, and **Z** is a vector of demand shifters, such as income, population, and prices of related goods. Processors buy live catfish as an input for their production, and they face a farm supply function as:

$$P_f = S(Q_f, \mathbf{W}) \qquad (2)$$

where, P_f is farm price, Q_f is farm sale volume, and **W** is a vector of catfish supply shifters, such as technology, and prices of feed, energy, capital and other inputs. We assume that processors all have the same 'fixed proportion' or Leontief production technology, or $Q_{f,i} = \kappa\, Q_{w,i}$. Where, $Q_{f,i}$ is farm-raised catfish volume bought by processing firm i, $Q_{w,i}$ is firm i's wholesale volume of processed catfish, κ is a constant, and $\kappa \geq 1$ (see Figure 1). Firm i's profit is:

$$\Pi_i = P_w(Q_w)\, Q_{w,i} - [P_f(Q_f)\, Q_{f,i} + C_i(\mathbf{r}, Q_{w,i})] \qquad (3)$$

where, Π_i is profit of firm i, Q_f is market farm supply ($Q_f = \Sigma Q_{f,i}$), Q_w is market wholesale volume ($Q_w = \Sigma Q_{w,i}$), C_i is firm i's processing cost, and **r** is a vector of prices of other inputs such as labor, energy, transportation, and capital. Firm i chooses to produce a quantity ($Q_{w,i}^*$) that maximizes its profit. The first order condition is $\partial\Pi_i/\partial Q_{w,i} = P_w + (\partial P_w/\partial Q_w)(\partial Q_w/\partial Q_{w,i})Q_{w,i} - \kappa P_f - (\partial P_f/\partial Q_f)(\partial Q_f/\partial Q_{w,i})Q_{f,i} - \partial C_i(\mathbf{r}, Q_{w,i})/\partial Q_{w,i} = 0$, where ∂ is a derivative operation. A number of manipulations yield a firm i's price equation:

$$P_w(1 + \theta_i/\eta) = \kappa P_f\,(1 + \theta_i/\varepsilon) + MC_i \qquad (4)$$

where, $\eta = (\partial Q_w/\partial P_w)(P_w/Q_w) < 0$ is the wholesale demand elasticity, $\varepsilon = (\partial Q_f/\partial P_f)(P_f/Q_f) > 0$ is the farm supply elasticity, and $\theta_i = (\partial Q_w/\partial Q_{w,i})(Q_{w,i}/Q_w)$ is the conjectural variation elasticity of firm i. MC_i is the marginal processing cost of firm i. Assuming that all catfish processing firms have the same technology with constant returns to scale (CRTS), hence marginal processing costs will be identical across firms, $MC_i = MC$. Multiplying firm i's price equation by its market share $(Q_{w,i}/Q_w)$, and summing over the number of firms, gains:

$$P_w(1 + \Theta/\eta) = \kappa(1 + \Theta/\varepsilon)P_f + MC \qquad (5)$$

where, $\Theta = \Sigma(Q_{w,i}\ \theta_i)/Q_w$ is the industry conjectural variation elasticity, ranging from 0 to 1. If $\Theta = 0$ processors face perfectly competitive farm and wholesale markets. If $\Theta = 1$, the processing industry is monopolistic and monopsonistic. If Θ ranges between 0 and 1, oligopoly power ($-\Theta/\eta$), and oligopsony power (Θ/ε) exist. Since no firm will operate where marginal revenue, $P_w(1 + \Theta/\eta)$, is negative, hence $1 + \Theta/\eta > 0$, or oligopoly only operates where $|\eta| > \Theta$. In case of $\Theta = 1$, demand must be elastic, $|\eta| > 1$ (Varian, 1992; p. 235).

Empirical Specification and Estimation

The test for market power involves an empirical estimation of a system of equations of output demand (1), farm supply (2), and price relation (5), and testing for the significance of conjectural variations elasticity (Θ). Hyde and Perloff (1995) found that the conjectural variations models are sensitive to choices of functional forms of (1), (2), and (5). Hyde and Perloff (1995) noted that the translog functional forms can reduce the probability of obtaining the true market structure by six folds compared to a correctly specified functional form.

In the previous studies of market power of the US catfish industry the issue of functional specification is not well addressed. Kouka (1995) assumed that the farm market is competitive and skipped farm supply in the testing of market power, despite that farm supply dynamics could affect processors' exertion of market power. Bouras and Engle (2007) considered farm supply estimation as a component in the testing of market power, but they left out possible long-run adjustments of catfish farm supply, despite the fact that changes in market power and structure are long-run. Bouras et al (2010) estimated a system of marketing margin, and farm supply equations. They specified the empirical farm supply model based on a vacant theoretical foundation. Overall, previous empirical tests on market power in the US catfish processing industry employed adhoc and weak theoretical foundation for the farm supply function, which is shown to be difficult to estimate, even separately, in the literature (Zidack, Kinnucan, and Hatch 1992, Kouka and Engle 1998).

In addition, all the previous studies did not test for misspecification errors in the system of market structural equations (Kouka 1995, Bouras and Engle 2007, Bouras et al 2010). The current study employs different empirical specifications of (1), (2), and (5) and conducts the specification error test for the system of equations. The best theoretical consistent empirical specifications are presented below. The empirical specification of the wholesale demand of output (1) is:

$$\log(Q_w) = a_0 + a_1*\log(P_w/CPI) + a_2*\log(GDP/CPI) + a_3*\log(POP) + a_4*\log(P_{meat}/CPI) + a_5*\log(Q_m) + \sum_{i=1}^{11} d_i D_i \quad (6)$$

where, Q_w is wholesale volume, P_w is wholesale price, CPI is consumer price index, P_{meat} is meat price index, GDP and POP are US gross domestic product, and population, Q_m is catfish imports. Variables D_i are dummies for months from January to November. Expected sign of a_1 is negative, and those of a_2 and a_3 are positive. The expected sign of a_5 is negative. The sign of a_4 is positive (negative) if meat is a substitute (complement) to catfish. The supply function (2) of farm-raised catfish is empirically specified using a normalized profit function approach (Nguyen, 2010). The empirical model of catfish farm supply is specified assuming that that farmers maximize both short-run and long-run profits. The normalized profit function (Yotopoulos and Lau, 1979) was employed to derive a supply function that accommodates both short and long run supply dynamics as below:

$$\log(Q_f) = \log(1-b_1-b_2-b_3) + b_1*\log(P_{feed}/P_f) + b_2*\log(P_{energy}/P_f) + b_3*\log(P_{capital}/P_f) + b_4*\log(Farmsize) + b_5*Year + \sum_{i=1}^{11} d_i D_i \quad (7)$$

where, Q_f is volume of catfish sold to processors, P_f is farm price, P_{feed} is catfish feed price, P_{energy} is energy price, $P_{capital}$ is bank prime interest rate, variable "Farmsize" is average water surface per farm, representing fixed inputs that affect long run adjustment of farm supply, "Year" is a time variable proxy for technological progress. The expected signs of b_1, b_2, and b_3 are negative. The expected signs of b_4 and b_5 are positive. Farm supply elasticity is equal to $-b_1-b_2-b_3$.

The second issue is the empirical specification of the conjectural variations elasticities (Θ). There are two common practices in empirical estimation of Θ, either considering Θ unchanged over study period, or letting Θ vary over time. Bouras et al (2010) considered Θ constant in their empirical estimation, while Kouka (1995) and Bouras and Engle (2007) considered Θ to vary over time and depends on exogenous input prices. In equilibrium or in the long run, it is believed that Θ is not a constant. Applebaum (1982) specifies Θ as a function of exogenous input prices. However, with the high frequent time series, e.g. monthly data, or in short run, exogenous input prices are not able to alter the market structure and behavior, hence are not good predictors of conjectural variations elasticity. Holloway (1991) and Schroeter and Azzam (1991) argue Θ vary with market structure and conduct proxy variables, such as the concentration ratio, the sizes and number of firms. The structural relationship between farm price and wholesale price is described in (5). In our study, we let Θ vary with market structure proxy variable, specifically, with the number of processors; $\Theta = e_0 + e_1$*Firm, where "Firm" is the number of catfish processors. However, we will estimate both specifications of Θ, constants vs. time-varying Θ, and conduct a specification test for deciding which one is a better fit for our data. The processing cost is assumed to take the generalized Leontief form. The empirical specification of (5) is:

$$
\begin{aligned}
P_w = {} & P_f*\{1 + (e_0 + e_1*Firm)/(-b_1-b_2-b_3)\}/\{1 + (e_0 + e_1*Firm)/a_1\} + \\
& \{c_0 + c_1*P_{labor} + c_2*P_{energy} + c_3*P_{transport} + c_4*P_{capital} + 2*c_5*(P_{labor}*P_{energy})^{0.5} + \\
& 2*c_6*(P_{labor}*P_{transport})^{0.5} + 2*c_7*(P_{labor}*P_{capital})^{0.5} + 2*c_8*(P_{energy}*P_{transport})^{0.5} + \\
& 2*c_9*(P_{energy}*P_{capital})^{0.5} + 2*c_{10}*(P_{transport}*P_{capital})^{0.5}\}/(1 + (e_0 + e_1*Firm)/a_1) \qquad (8)
\end{aligned}
$$

where, P_{labor} is wage index, $P_{transport}$ is transportation price index. The expected sign of e_0 is positive and that of e_1 is negative.

Data used in this study are monthly, available from January 1988 to December 2008. Catfish data are from various USDA reports. Catfish feed prices are from Hanson and Sites (2010).

Non-farm input price indices are from The Bureau of Labor Statistics. Other data are from The Bureau of Economic Analysis (BEA), and the US Census. Table 1 below shows the variable description.

The system of (6), (7), and (8) is estimated using the nonlinear three-stage least squares (N3SLS) method. The three-stage least squares (3SLS) estimator is consistent, more efficient, and superior to the two-stage least squares (2SLS) estimator when there are correlations between disturbances of different equations, and cross-equation constraints of parameters. In addition, the N3SLS estimator is more robust than the maximum likelihood estimator (MLE) when dealing with non-normality problem (Amemiya, 1977). However, the N3SLS only works well when there is no misspecification errors. We conduct Hausman specification tests with the null hypothesis (Ho) of “all equations are properly specified” versus the alternative hypothesis (Ha) of “at least one equation is misspecified”. We, first, estimate the system of (6), (7), and (8) with the consideration of Θ as a constant. The results are in Table 2 below.

We see that the empirical results in Table 2 follow the theoretical expectations for the conjectural variations model. The demand and supply equations conform to the demand and farm supply theory. The estimate of the conjectural variation elasticity is statistically significant. Hausman specification test gives computed statistics of 113.7. The Chi square 5% critical value for the 42 degree of freedom is 27.87. We reject Ho, indicating that the model is misspecified. We estimate the empirical models again with the specification of Θ as a function of the number of processing firms. The results are in Table 3 below.

The Hausman specification test statistics is 17.9; Chi square 5% critical value at a degree of freedom of 43 is 28.69. We fail to reject the Ho of “all equations are properly specified”, indicating that empirical models are correctly specified. Estimated results of wholesale demand show the anticipated negative sign for wholesale price (P_w) with demand elasticity (η) of -0.52. Income has a significant positive effect with an income elasticity of 0.61, implying that catfish is a normal good. Import has a negative effect on domestic demand as anticipated. The estimated farm supply elasticity (ε) is 0.12. All input prices negatively affect farm supply. Technological progress has a positive effect on farm supply. Farmsize, proxy for fixed factors, also has a positive effect as anticipated. The magnitude of estimated coefficient of Farmsize is 0.41 < 1 implying that the US catfish farm-raised production is at the stage of decreasing returns to scale. The estimation of the price equation gives an estimate of conjectural variations elasticity of $\Theta = e_0 + e_1$*Firm = 0.07. As expected, the sign of e_0 is positive, and the sign of e_1 is negative, implying that with larger numbers of processing firms the processing sector will have smaller market power. The empirical results conform to the theoretical constraint that oligopoly operates where $| \eta | > \Theta$, or 0.52 > 0.07. The oligopoly power index of the US catfish processing sector is $- \Theta/\eta = 0.14$, and the oligopsony power index is $\Theta/\varepsilon = 0.6$.

The validity of the basic assumptions such as fixed proportion, and constant returns to scale (CRTS) in processing technology are essential. The assumption of fixed proportion technology seems appropriate in the US catfish processing industry because processing yield rate is relatively fixed at 62% for whole catfish, and 43% for fillet, and about 50% for aggregate level (Silva and Dean, 2001), Figurer 1. Therefore, the ratios $\kappa = 2.0$ for the aggregate model is assumed. We performed a regression-based test of κ = f(Farm price, Input prices, Trend). Input prices are labor, energy, and capital prices. Trend variable represent the changing of technology over time. The regression results show that none of the predictors statistically affect the value of κ. Therefore, we can conclude that the US catfish processing sector has a fixed proportion technology during the study period. We also test for the constant return to scale (CRTS) in the

US catfish processing industry. The CRTS technology means that marginal cost (MC) of processing is constant or unchanged over time with different output levels (Q_w). We conducted a regression-based test model of MC = f(Q_w, Trend), with the null hypothesis of Ho: $\Delta MC/\Delta Q_w$ = 0. The estimated regression is MC = 1.36 - 0.00003*Q_w - 0.0021*Trend + 0.996*lag(MC). The computed t-statistics with Q_w is -0.72, and p-value is 0.47, we fail to reject the null hypothesis, and conclude that the US catfish processing industry is at the stage of constant returns to scale.

The conjectural variation elasticity varies over the time with the change in the number of catfish processing firms. The elasticity fell to the lowest level in 1990 when the number of processing firms reached its largest number. In recent years, the number of catfish processing plants decrease, which leads to the increase in the conjectural variation elasticity, see Figure 2. During the study period of 1988 to 2008, the average observed processed catfish price is 226.35 cent/lb, and farm price received by catfish growers is 71.48 cent/lb. With market power, the catfish processors keep paying low prices to catfish growers. In case of $\varepsilon = 0.12$, catfish growers receive a farm price that is 42.75 cent lower than the 'competitive price' (P_{f0}) of live catfish; P_{f0} is the price of live catfish received by growers in case catfish processors behave competitively. When considering long run responses of farm supply, we simulate the effects of market power on farm price in the cases of $\varepsilon = 0.3$, $\varepsilon = 0.5$. Farm price will drop by 16.88 cent/lb and 10.13 cent/lb from its 'competitive' price with $\varepsilon = 0.3$ and $\varepsilon = 0.5$, respectively. The results in Table 4 show that processors exert stronger market power on catfish growers when the farm supply is less elastic. If the US catfish processors behave competitively, they can bid up price paid to catfish growers up to 114.23 cent/lb in case of $\varepsilon = 0.12$, and up to 88.36 cent/lb and to 81.61 cent/lb in cases of $\varepsilon = 0.3$ and $\varepsilon = 0.5$, respectively.

With the market power, catfish processors can also overcharge buyers with a price that is higher than the ‘competitive price’ (P_{w0}) of processed catfish; P_{w0} is the wholesale price in the case if processors behave competitively. In different cases of η = -0.52, η = -1, and η = -1.5, catfish processors can overcharge buyers with prices that are 30.97 cent/lb, 16.04 cent/lb , and 10.69 cent/lb higher than the ‘competitive price’ of processed catfish. The results show that catfish processors will have less ability to exert market power on catfish buyers when the wholesale demand is more responsive. If the US catfish processors behave competitively, the wholesale price paid by buyers will be 195.38 cent/lb in case of η = -0.52, 210.31 cent/lb in case of η = -1, and 215.66 cent/lb in cases of η = -1.5.

Processed catfish has four cost components, namely live catfish cost, marginal processing cost (MPC), farm input induced ($(\Theta/\varepsilon)P_f$), and output price induced ($(\Theta/|\eta|)P_w$). Live catfish accounts for 61.5% of cost share of processed catfish during the study period. The US catfish processors overcharge catfish buyers an amount of money ($(\Theta/|\eta|)P_w$) that equals to 5% to 14% of the unit value of processed catfish. At the same time, the processors extract profits from paying low prices to catfish growers, and that equals to about 9% to 37% of the unit value of processed catfish. Marginal processing cost (MPC) is the cost of producing one unit of processed catfish output that excludes live catfish cost. MPC is generated from labor cost, energy cost, capital cost in the catfish processing industry. In the long run, MPC is about 57 cent/lb, which is similar to the calculations of 63 cent/lb in Kaliba and Engle (2003).

The marginal processing cost, $MPC = P_w - \kappa^*P_f - \kappa^* (\Theta/\varepsilon)P_f + (\Theta/|\eta|)P_w$, is stable over time and inspite of relatively large changes of the live catfish cost component, reflecting that the US catfish processing industry has a constant returns to scale (CRTS) technology (Figure 3). We notice that there were two points in time, 1991/1992 and 2002/2003, in the study period where the catfish cost component dropped significantly. When looking at historical price data, we found that at these points in time, farm price and wholesale price dropped to their lowest levels in the study period. The period of 1991/1992 coincides with the time when the processing sector have the largest number of processing plants, and moved closer to a competitive market. The period of 2002/2003 is the time when the US industry realized fierce competition from catfish-like imports, and the industry was about to impose an unti-dumping tariff on catfish-like imports.

Since 2003, the US catfish industry has been losing its market share continuously; the share of US frozen fillet dropped from 80% in 2005 to 26% in 2011, especially, between 2010 and 2011 the share dropped from 42% to 26%. The US catfish industry has been reaching out for possible interventions to reverse the down swing of the industry. High input costs and fierce competition from imports are the mostly cited reasons thus far for the decline of US farm-raised catfish. However, imperfect market structure and non-competitive behavior could be a factor deterring the industry competitiveness. Hence any potential policy intervention and its effectiveness should be placed and discussed in the context of market structure and potential impacts of market power on that intervention. In the following section, we discuss the welfare effects of market power, and potential policy intervention to enhance the long run development of the industry.

Welfare Effects and Policy Discussion

At the farm market level, processors' oligopsony power lowers price paid to catfish growers by reducing their purchased quantity, and that results in welfare loss to catfish growers. The catfish producers will have a welfare loss (ΔPS_f) that is equal to the area of (A + B + C) in Figure 4. Or, $\Delta PS_f = ½ (P_{f0} - P_f)*(Q_f + Q_{f0})$, where, P_f and Q_f are price and volume that are actually observed on the farm market. P_{f0} and Q_{f0} are 'competitive' price and 'competitive' volume when processors bahave competitively. $P_{f0} = (1 + \Theta/\varepsilon)P_f$. Farm supply elasticity $\varepsilon = (\Delta Q_f/\Delta P_f)*(P_f/Q_f) = \{(Q_{f0} - Q_f)/(P_{f0} - P_f)\}*(P_f/Q_f)$, hence $Q_{f0} = \varepsilon*Q_f*(P_{f0} - P_f)/P_f + Q_f = (1 + \Theta)Q_f$. To substitute $P_{f0} = (1 + \Theta/\varepsilon)P_f$ and $Q_{f0} = (1 + \Theta)Q_f$ into the formula of $\Delta PS_f = ½ (P_{f0} - P_f)*(Q_f + Q_{f0})$, to obtain:

$$\Delta PS_f = ½\, P_f*Q_f*(\Theta/\varepsilon)*(2 + \Theta) \qquad (9)$$

In contrast, the catfish processors will gain a welfare (ΔCS_f) that is equal to the area of (A + B - D) in Figure 4, or $\Delta CS_f = ½ (P_{f0} - P_f)*Q_f - ½ (P_f' - P_{f0})*(Q_{f0} - Q_f)$. Let η_f be demand elasticity of catfish at the farm market; hence, $\eta_f = \{(Q_{f0} - Q_f)/(P_{f0} - P_f')\}*(P_{f0}/Q_{f0})$. Therefore, $P_f' - P_{f0} = \{(Q_f - Q_{f0})*P_{f0}\}/(Q_{f0}*\eta_f)$. To substitute $(P_f' - P_{f0})$, P_{f0}, and Q_{f0} into the formula of $\Delta CS_f = ½ (P_{f0} - P_f)*Q_f - ½ (P_f' - P_{f0})*(Q_{f0} - Q_f)$, to obtain:

$$\Delta CS_f = ½\, P_f*Q_f*(\Theta/\varepsilon) + ½\, P_f*Q_f*\Theta^2*(1 + \Theta/\varepsilon)/\{(1 + \Theta)*\eta_f\} \qquad (10)$$

Total deadweight loss at the farm market due to the oligopsony power of the catfish processors is $\Delta TS_f = \Delta PS_f - \Delta CS_f = (C + D)$.

At the wholesale market, the welfare effects caused by oligopoly power are also examined. The welfare loss to buyers of processed catfish (ΔCS_w) is equal to the area of (E + F + G) in Figure 5, Or, $\Delta CS_w = ½ (P_w - P_{w0})*(Q_w + Q_{w0})$. P_w and Q_w are observable price and volume. P_{w0} and Q_{w0} are 'competitive' price and volume at a perfectly competitive wholesale market. Where, $P_{w0} = (1 + \Theta/\eta)P_w$, and $Q_{w0} = (1 + \Theta)Q_w$. To substitute P_{w0} and Q_{w0} into formula of $\Delta CS_w = ½ (P_w - P_{w0})*(Q_w + Q_{w0})$, yields:

$$\Delta CS_w = -\, ½\, P_w*Q_w*(\Theta/\eta)*(2 + \Theta) \qquad (11)$$

At the same time, the processors gain a welfare (ΔPS_w) that is equal to the area of (E + F - H) in Figure 5, or $\Delta PS_w = ½ (P_w - P_{w0})*Q_w - ½ (P_{w0} - P_w')*(Q_{w0} - Q_w)$. Assuming that ε_w is supply elasticity at the wholesale market, hence $\varepsilon_w = \{(Q_{w0} - Q_w)/(P_{w0} - P_w')\}*(P_{w0}/Q_{w0})$. Therefore, $P_{w0} - P_w' = \{(Q_{w0} - Q_w)*P_{w0}\}/(Q_{w0}*\varepsilon_w)$. To substitute $(P_{w0} - P_w')$, P_{w0}, and Q_{w0} into the formula of $\Delta PS_w = ½ (P_w - P_{w0})*Q_w - ½ (P_{w0} - P_w')*(Q_{w0} - Q_w)$, one obtains:

$$\Delta PS_w = ½ P_w*Q_w*(-\Theta/\eta) + ½ P_w*Q_w*\Theta^2*(1 + \Theta/\eta)/\{(1 + \Theta)*\varepsilon_w\} \qquad (12)$$

Total deadweight loss at the wholesale market that is caused by the processors oligopoly power is $\Delta TS_w = \Delta CS_w - \Delta PS_w = (G + H)$.

The welfare distributions at the farm and wholesale markets are computed with three different scenarios of farm supply elasticity (ε) and wholesale demand elasticity (η). The first scenario used the values of farm supply and wholesale elasticities obtained empirically in this study; $\varepsilon = 0.12$ and $\eta = -0.52$. These elasticities show the short run and spontaneous responses of farm supply and wholesale demand to the changes in prices. In the long run, both farm supply and wholesale demand will be more responsive to the changes in prices; hence we will simulate the effects of market power with higher values of farm supply and wholesale demand elasticities. The results are presented in Table 5.

Processors have a market power that forces the price paid to farmers down by 10-43 cents/lb from its 'competitive' price, depending on the magnitudes of farm supply elasticity. The US catfish farm supply is very inelastic ($\varepsilon = 0.12$) in short run, and the processors could abuse their market power to force price paid to catfish growers down by 40 cent/lb. However, in the long run when farm supply is responsive, the processors are unable to use their market power as much on catfish growers. For example, when $\varepsilon = 0.3$ and 0.5, processors can only force price paid to growers down by 17 and 10 cent/lb from its ‘competitive’ price, respectively. The results imply that the US farm-raised catfish should find ways to increase its supply flexibility, both in the short and long run, to reduce negative effects of market power. In the past, the industry has employed several measures such as multiple batch production, partial harvest to spread farm supply over time, and forming the US catfish growers association to increase bargaining power. However, there is no study to evaluate the effects of those interventions on the welfare of US catfish growers. The current study can be a good framework for evaluating those interventions.

The results in Table 5 show that market power causes a welfare loss of $4.4 million to $18.6 million per month. In other words, US catfish growers lose at least about $52 million per year due to market power exerted by the processors. Further studies are needed to scrutinize on the competitive characteristics of US catfish processors. For example, the US catfish processors require live catfish delivered to processing plants to be of specific size per fish. This regulation may limit the flexibility of the US farm-raised supply function, and it in turn exacerbates the effects of market power of processors over catfish growers. More than 90% of live catfish are delivered to the catfish processing sector. In the future, the US farm-raised industry should seek to diversify its market channels to local and overseas markets.

The current study has several limitations that can be examined in future research of market power in the US catfish industry. First, the current study employs the system of equations and econometric method to estimate the market structure, and to test for market power. The method is very sensitive to measurement and misspecification errors, and requires us to conduct an extensive survey of functional forms and specifications. Even though we proposed an empirical specification that conformed to microeconomic theory, and passed the Hausman tests for no misspecification errors; there is a need to further verify our empirical results using different empirical estimation methods, which are less sensitive to functional forms, as discussed in Hyde and Perloff (1995). Second, the current study uses a static framework in the model and empirical estimation method. Future research in this topic can employ time series techniques to estimate short run and long run reactions of market participants to market power and its effects. Third, the current study assumes a simple Cournot competition framework, where firms compete over quantities. Future studies of the US catfish market power can test for different competitive game strategies among the US catfish processing firms.

Conclusions

The current study employs the conjectural variations model to test for market power, and evaluates the effects of market power in the US catfish industry. The additional contribution of this study, compared to previous studies of market power in the US catfish, is that we proposed an empirical model that is based on microeconomic theory, free of misspecification errors. Therefore, our empirical results are reliably compared to previous studies on the US catfish industry. We found the existence of market power of the US catfish processing sector. The estimated conjectural variation elasticity is 0.07, and the ability of the processors to exert their market power on catfish growers and buyers depends on the flexibility of the farm supply and wholesale demand functions. In the short run, the US catfish processors can force price paid to catfish growers down by 37% or 43 cent/lb from its ‘competitive’ price, but in the long run these figures are 12%, or 10 cent/lb respectively. If the US catfish processors behave competitively, the US catfish growers will gain at least $52 million per year. The obvious measure that the US farm-raised catfish industry can adopt to deter the negative effects of market power is to increase its farm supply flexibility. For example, if farm supply elasticity increases from 0.3 to 0.5, the

US farm-raised catfish will gain about $36 million a year. Further studies of market power in the US catfish industry are needed to verify the empirical results of the current study. In addition, future studies can extend the current study to address the dynamic issue in the models and empirical estimation, and to test for different competitive strategic behaviors among the US catfish processing firms.

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Table 1. Variable Description

Variables	Unit	Mean	Std. Dev.	Minimum	Maximum
Farm volume	1000 lb	42,208.9	8,964.7	20,355.5	65,021.3
Farm price	Cent/lb	71.9	7.7	52.9	84. 0
Processor volume	1000 lb	21,095.9	4,353.4	10,498.4	30,491.7
Processor price	Cent/lb	226.4	15.3	186.4	260.0
Import of catfish	1000 lb	1,533.9	2,627.6	-	12,832.9
Feedp rice	$/ton	242.9	45.2	186.0	442.0
Farm size	Acre	159.9	54.1	64.9	212.3
Firm	Number	25.8	4.1	18.0	37.0
Meat price	Index	151.9	25.8	110.1	209.7
Energy price	Index	129.4	41.4	86.5	280.8
Wage	Index	81.5	15.1	57.1	107.7
Transport price	Index	146.9	23.2	106.5	212.8
Interest	%	7.5	1.9	3.6	11.5
GDP	Billion $	10,337.5	1,901.7	7,496.6	13,415.3
POP	Million	274.9	18.4	244.5	304.1

Table 2. N3SLS Estimation with a Constant Conjectural Variations Elasticity

Price equation: P_w		Wholesale demand: $\log(Q_w)$		Farm supply: $\log(Q_f)$	
Variable	Estimate	Variable	Estimate	Variable	Estimate
Constant (c_0)	52.626**	Constant	1.747	constant	n/a
	(9.53)		(0.84)		
P_{labor}	1.555	$\log(P_w/CPI)$	-0.524**	$\log(P_{feed}/P_f)$	-0.049
	(1.16)		(-5.99)		(-1.10)
P_{energy}	0.535	log(GDP/CPI)	0.58*	$\log(P_{energy}/P_f)$	-0.026
	(1.15)		(2.19)		(-0.71)
$P_{capital}$	-5.599**	log(POP)	0.560	$\log(P_{capital}/P_f)$	-0.120**
	(-5.63)		(0.74)		(-4.03)
$P_{capital}*P_{transport}$	1.466*	$\log(P_{meat}/CPI)$	-0.729**	log(Farmsize)	0.407**
	(2.83)		(-4.86)		(17.26)
Θ	0.077**	$\log(Q_m)$	-0.058**	Year	0.004**
	(5.30)		(-9.24)		(55.60)

Note: *significant at 5%; **significant at 1%; t-values are in brackets

Table 3. N3SLS Estimation with a Time-varying Conjectural Variations Elasticity

Price equation[a]: P_w		Wholesale demand: $\log(Q_w)$		Farm supply: $\log(Q_f)$	
Variable	Estimate	Variable	Estimate	Variable	Estimate
Constant (c_0)	57.721***	Constant	1.753	constant	n/a
	(9.68)		(0.87)		
P_{labor}	2.575*	$\log(P_w/CPI)$	-0.518***	$\log(P_{feed}/P_f)$	-0.025
	(1.85)		(-6.06)		(-0.54)
P_{energy}	0.911*	log(GDP/CPI)	0.606**	$\log(P_{energy}/P_f)$	-0.033
	(1.9)		(2.36)		(-0.85)
$P_{capital}$	-4.800***	log(POP)	0.516	$\log(P_{capital}/P_f)$	-0.118***
	(-4.72)		(0.70)		(-3.88)
$P_{labor}*P_{energy}$	-1.612*	$\log(P_{meat}/CPI)$	-0.693***	log(Farmsize)	0.409***
	(-1.88)		(-4.74)		(16.74)
$P_{capital}*P_{transport}$	1.409***	$\log(Q_m)$	-0.058***	Year	0.004***
	(3.26)		(-9.54)		(53.37)
Constant (e_0)	0.0811***	-		-	
	(4.79)				
Firm (e_1)	-0.0004**	-		-	
	(-2.37)				

Note: *significant at 10%; **significant at 5%; ***significant at 1%; a) Price equation is reported with all significant variables.

Table 4. Cost Components of Processed Catfish

Components	$\varepsilon = 0.12, \eta = -0.52$		$\varepsilon = 0.3, \eta = -1$		$\varepsilon = 0.5, \eta = -1.5$	
	Unit value (cent/lb)	Share (%)	Unit value (cent/lb)	Share (%)	Unit value (cent/lb)	Share (%)
Processed catfish	226.35	100.00	226.35	100.00	226.35	100.00
Farm catfish	71.48	61.47	71.48	61.47	71.48	61.47
$(\Theta/\lvert\eta\rvert)P_w$	30.97	13.67	16.04	7.08	10.69	4.72
$(\Theta/\varepsilon)P_f$	42.75	36.74	16.88	14.51	10.13	8.69
MPC	-27.38	-11.87	38.01	16.95	56.52	25.11
P_{w0}	195.38	15.84	210.31	7.62	215.66	4.95
P_{f0}	114.23	37.41	88.36	19.09	81.61	12.40

Note: MPC is marginal processing cost; $P_w = \kappa^*(P_f + (\Theta/\varepsilon)P_f) + (\Theta/\lvert\eta\rvert)P_w + MPC$, when $\kappa = 2$

Table 5. Welfare Distributions due to Market Power

Parameters	Unit	Farm market (Oligopsony)			Wholesale market (Oligopoly)		
		$\varepsilon = 0.12$	$\varepsilon = 0.3$	$\varepsilon = 0.5$	$\eta = -0.52$	$\eta = -1$	$\eta = -1.5$
ΔPrice	cent/lb	- 42.8	- 16.9	-10.1	31.0	16.0	10.7
ΔVolume	1000 lb/month	-2,995.8	-2,995.8	-2,995.8	-1,497.0	-1,497.0	-1,497.0
ΔCS	1000 $/month	8,874.3	3,460.4	2,048.0	-6,786.6	-3,514.3	-2,342.9
ΔPS	1000 $/month	-18,613.2	-7,347.5	- 4,408.5	3,374.0	1,801.5	1,238.5
ΔTS	1000 $/month	- 9,738.9	-3,887.1	-2,360.5	-3,412.6	-1,712.9	-1,104.4
Revenue	1000 $/month	29,971.9	29,971.9	29,971.9	47,781.9	47,781.9	47,781.9

Note: assuming wholesale supply $\varepsilon_w = 1$, and farm input demand $\eta_f = -1$.

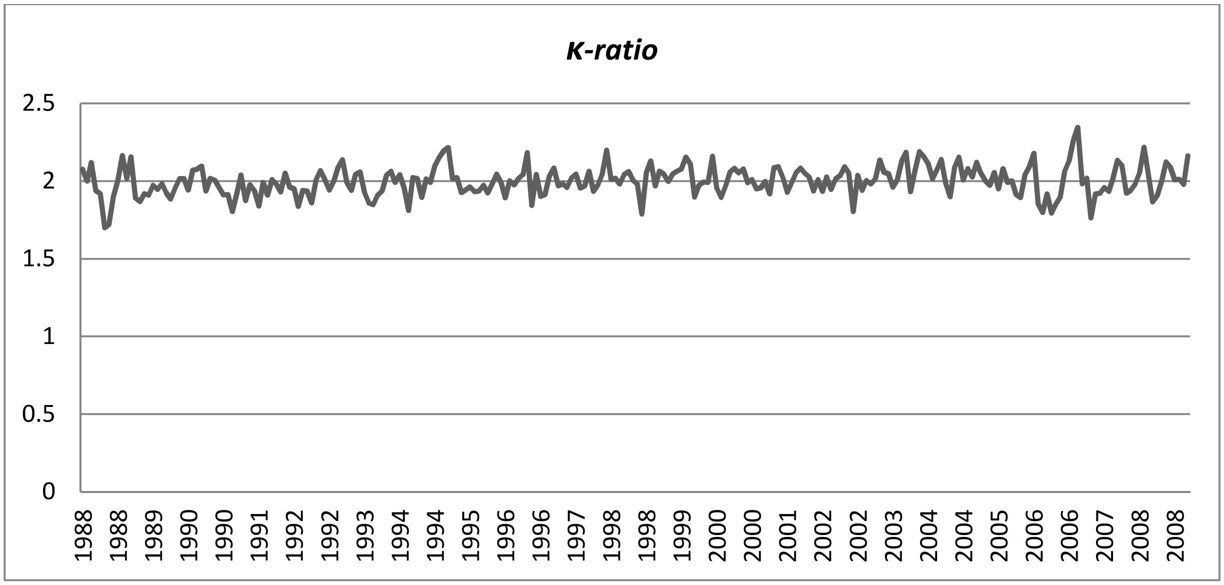

Figure 1. *K*-ratio = Farm volume/Wholesale volume.

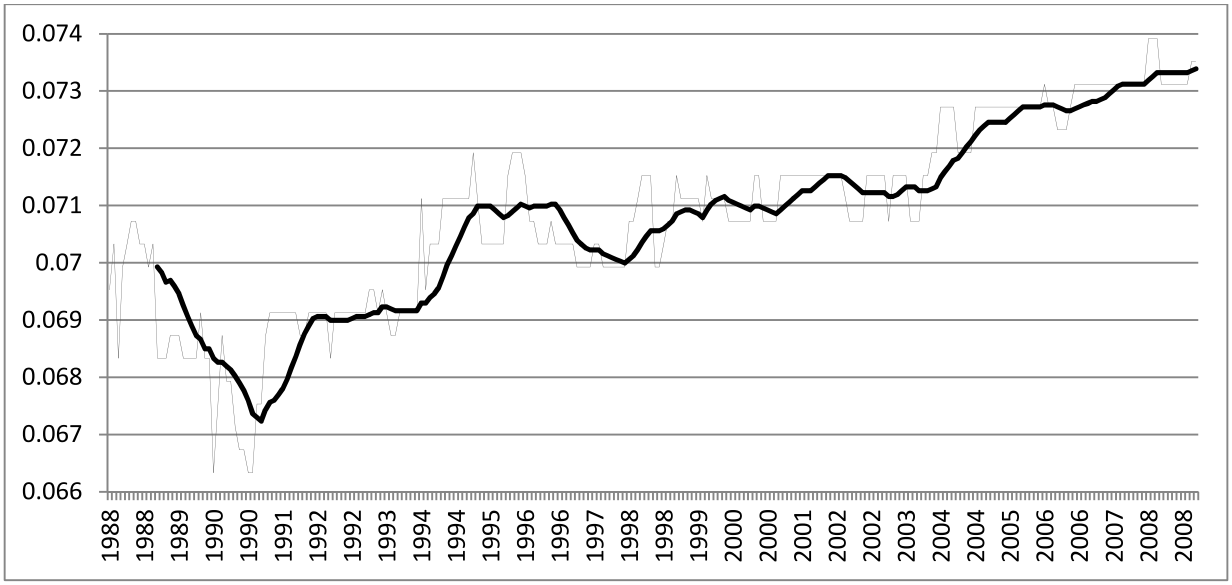

Figure 2. Conjectural Variation Elasticity

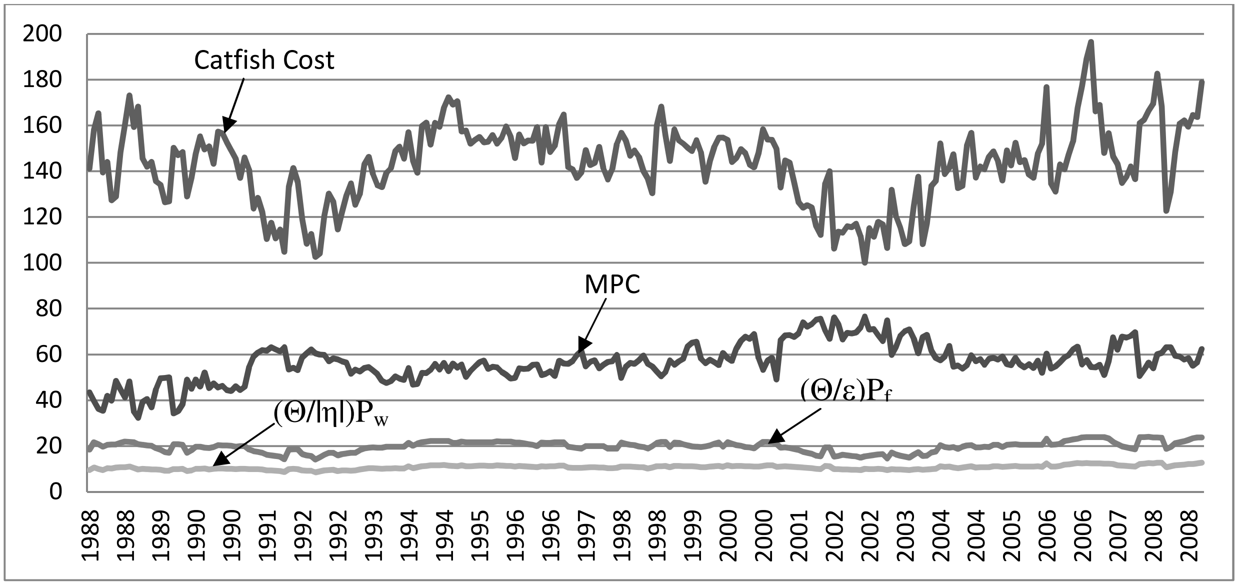

Figure 3. Cost Components of Processed Catfish (cent/lb)

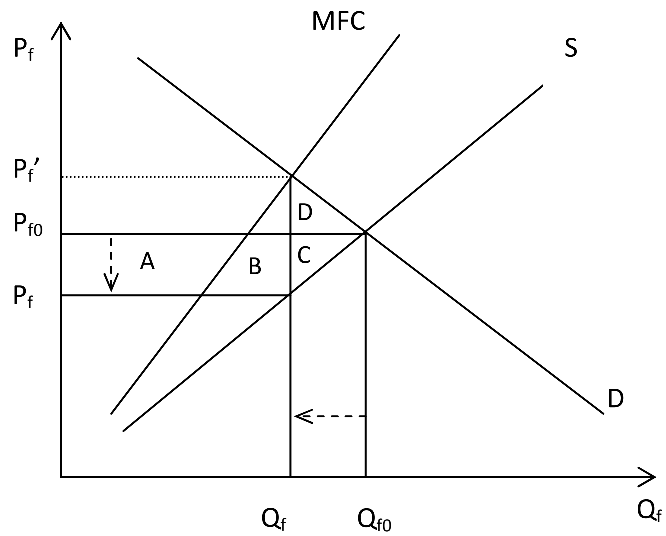

Figure 4. Welfare Distributions at the Farm Market

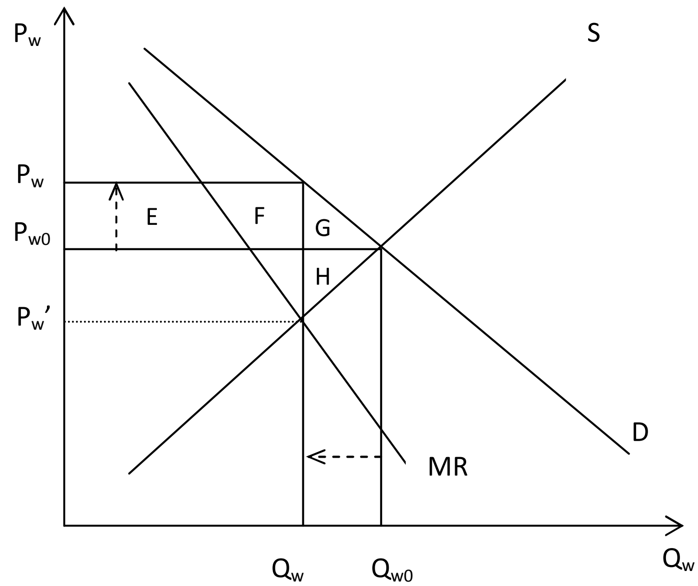

Figure 5. Welfare Distributions at the Wholesale Market