Supply Response, Price Transmission, and Risk in the U.S. Catfish Industry

by

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Abstract

The dissertation is organized into three topics in economic analysis of the U.S. farm raised catfish industry. The objective is to evaluate the supply response, price transmission in an imperfect market, and risk transfer between processing and farm market level in the U.S. catfish industry.

The first topic studies the U.S. farm raised catfish supply using a static normalized profit function and dynamic adaptive expectation approaches. Empirical estimations of short-run supply elasticities are 0.23 and 0.28, and long-run supply elasticities are 0.80 and 2.1 when using static and dynamic approaches. Only 8.5% out of 72.7% of catfish farm supply increase between 1988 and 2008 is attributed to technological change. Catfish producers adjust yield in the short-run and acreage in the long-run to respond to market incentives. Catfish supply varies inversely with risks.

The second topic studies the transmission between catfish farm and processed prices. The theoretical model predicts that price transmission is asymmetric, and the transmission elasticity ranges between 0 and 1. Market power at the processing level has a positive effect on price transmission, meaning that farm price is transmitted more completely to wholesale price when processors have more power over catfish producers. However, market processors' power has an ambiguous effect on the asymmetric level of price transmission. The empirical test finds a short-run price transmission elasticity of 0.40, and long-run of 0.60. Co-integration test results in a short-run elasticity of 0.45 and a long-run of 0.73. Sixty-two percent of positive price transmissions and 40% of negative price transmissions are realized spontaneously. The industry conjectural variation elasticity is 0.06. Processors have oligopoly and oligopsony power that force farm price down, and raise wholesale price at the same time.

The third topic investigates the effects of price risk originated at processing on farm raised catfish supply. A theoretical model predicts that price risks at the processing level may affect factor demand for farm raised catfish. Fluctuations in factor demand may also influence the catfish farm supply response. Input/output price expectations at processing and marketing levels may have negative/positive effects on factor demand at the farm level. Price risks reduce processor factor demand for farm raised catfish. Empirical results show evidence that price risks at processors level reduce catfish farm raised supply. In terms of product forms, fillet products have positive effects on farm supply, while whole fish products have a negative relationship with farm supply.

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INTRODUCTION

Catfish production contributed the largest share of U.S. aquaculture sales in 2007. The industry enjoyed a long period of growth from 1970 to 1990 but experienced reductions in water acres, output, and sales since 2000. The decline is attributed primarily to competition from catfish-like imports (Jolly et al., 2001; Kennedy and Lee, 2005; Quagrainie, 2006; Lee and Kennedy, 2009), and recent increases in feed and fuel costs (Byrd, 2008). The challenges faced by the U.S. catfish industry have triggered a desire to analyze and forecast the impacts of the escalation in feed price and catfish-like import on the industry. A thorough analysis of this kind requires knowledge of catfish farm supply. However, estimates of the U.S. catfish farm supply, to date, are inconsistent, unreliable, and in most cases generate insignificant and unstable coefficients (Kinnucan and Sullivan, 1986; Zidack, Kinnucan, and Hatch, 1992; Kouka and Engle, 1998). Therefore, there is a critical demand for a timely, comprehensive, and rigorous estimation of the U.S. catfish farm supply.

Knowledge of price transmission between the U.S. catfish farm and wholesale markets is crucial in gaining an in depth understanding of market structure and behaviors. Numerous studies have examined vertical price transmission in the U.S. catfish industry (Kinnucan and Sullivan, 1986; Kinnucan and Wineholt, 1988; Nyankori, 1991; Zidack et al, 1992; Hudson; 1998; Hudson and Hanson, 1999; Buguk, Hudson, and Hanson 2003; Kinnucan and Miao, 1999). Those studies found evidences of price transmissions from farm to wholesale markets. The magnitude of price transmission elasticities varies across studies, such as 0.29 in Kinnucan and Wineholt (1988), 0.68 in Zidack et al. (1992), 0.41 in Kinnucan (1995), 0.64 in Kinnucan and Thomas (1997), 0.63 in Kinnucan and Miao (1999), and 0.29 in Kinnucan, Sindelar, and Hatch (1988). None of the previous studies tested asymmetry in price transmission, as well as possible problems when dealing with non-stationary time series.

The literature on market power in the U.S. catfish industry is mixed. Kouka (1995) finds evidence of oligopolistic power and some degree of price enhancement. Hudson (1998) tests imperfect competition in the U.S. catfish market using conjectural variation, and concludes that the U.S. catfish market is competitive. Hudson and Hanson (1999) analyzed marketing margin using the number of processing plants as a proxy for market concentration, and found that the number of processing plants has no effect on farm-wholesale price spread. Bouras and Engle (2007) found oligopoly power index of 0.28, and oligopsony power index of 0.68, but their estimates of market power are statistically insignificant.

The literature on the catfish industry market has left some unresolved questions, such as: Is there any asymmetry in price transmission between farm and wholesale markets? What are the factors attributable to the asymmetry? How does market power play a role in price transmission?

Risks are unavoidable in aquaculture production. Previous studies on risk in the U.S. catfish industry include Branch and Tilley (1991), Losinger (2006), Soto & Kazmierczak (2000), Neira and Quagrainie (2007). The main production risk in the U.S. catfish farming is the off-flavor problem (Branch and Tilley, 1991). Output price risk positively affects catfish producers' decision on harvesting volume (Branch and Tilley, 1991). Losinger (2000) finds that farm and pond sizes are significant influences on yield risk. Larger farms have a competitive advantage over small farms in terms of higher yield and lower variance. Larger pond sizes have higher variance in catfish yield (Losinger, 2000). Similarly, Soto & Kazmierczak (2000) find that the single-batch production system for small size farms was the most inefficient production type in terms of high risks in yield and net returns.

Neira and Quagrainie (2007) use a principal-agent model to examine risk behavior among catfish producers and processors. They find that catfish processors do not shift market risks to catfish producers, and producers are paying high premiums by receiving low prices for their live catfish. Neira and Quagrainie (2007) also find no evidence of production risk shifting from farmers to processors. The existing literature on the catfish industry lacks discussion on the effect of risks at the processing level on farm market.

Since the late 1980s, there has been a dramatic change in the structure of processed forms in U.S. catfish processing. Fillet and frozen products have been developed that gradually replaced market shares of fresh and whole fish products. Recently, steak and nuggets have been promoted by processors. The diversification process in product form of the U.S. catfish processing industry raises some questions. Those research questions are: What are the incentives for processors to diversify their products? How is product diversification related to processing risks in the U.S. catfish industry? Does product diversification in catfish processing have any impact on the U.S. catfish producers at the farm level?

The purpose of this dissertation is to provide a comprehensive economic analysis of the U.S. catfish industry. Specifically, I will investigate how catfish producers respond to changing market conditions of rising input prices, survive competition from imports, and deal with harsh macroeconomic conditions. The relationship between producers and processors is also investigated through examining the behavior of price transmission between markets and possible exertion of market power. Finally, I will discuss the effects of risks at farm and processors market on catfish producers' behavior, and the implication of changing product forms at processing level on farm production.

The dissertation employs a static normalized profit function and adaptive expectation methods to estimate U.S. catfish farm supply. Incremental contributions are to include fixed factors and risk factors in the supply function; and to separate the responses of acreage and yield in the supply response. The Houck (1977) method and cointegration are employed to detect asymmetry in price transmission. Market power is tested using the new institutional approach to industrial organization to estimate the industry conjectural variation elasticity and market power indices. Risk response of catfish farm production is analyzed using a Just-Pope (1979) production function with multi-output and multi-inputs to examine the effects of risk created by specific product form at processing.

The dissertation is organized with the following sections. Chapter 1 discusses the economics of the U.S. catfish farm supply with the specific objectives: (1) to estimate farm supply functions of the U.S. catfish farm industry; (2) to determine factors affecting the U.S. catfish supply's responses to prices and market forces; and (3) to evaluate the risks associated to catfish farm supply.

Chapter 2 investigates the asymmetric price transmission and market power in the U.S. catfish industry. The specific objectives are: (1) to test the asymmetry in price transmission between farm price to wholesale price; (2) to test the linkage between market power and price transmission in the U.S. catfish processing sector; (3) to investigate the welfare distribution between producers, processors, and consumers in the presence of asymmetric price transmission and market power in the U.S. catfish industry.

Chapter 3 deals with product diversification at processing level and risk transfer from processing to U.S. farm raised catfish. The specific objectives are: (1) to investigate motivations of product diversification and its impacts on risk and profitability of the U.S. catfish processing industry; (2) to investigate the effects of different processed catfish products, such as whole fish, fillet, steak, fresh vs. frozen, on the behavior of the U.S. catfish producers regarding risk and supply.

The results from these studies will be useful for researchers and policy makers in designing appropriate measures to improve competiveness of the U.S. farm raised catfish. For example, the results from Chapter 1 can be used to diffuse information on farm supply elasticity which can be used to simulate the impacts of rising input price. The results from Chapter 2 can be used to inform the public about the economic loss when processors exert market power. The results from Chapter 3 can direct future research on farm production to respond to the changes and trend of product form innovations at the processing market level.

CHAPTER 1: ECONOMICS OF THE U.S. CATFISH FARM SUPPLY

1. Introduction

Catfish production contributed the largest share of U.S. aquaculture sales in 2007. This amounted to 32% or 455 million U.S. dollars (USDA, 2009). The industry enjoyed a long period of growth from1970 to 1990, but experienced reductions in water acres, output, and sales since 2000. The decline is attributed primarily to competition from catfish-like imports (Jolly et al., 2001; Kennedy and Lee, 2005; Quagrainie, 2006; Lee and Kennedy, 2009), and recent increases in feed and fuel costs (Byrd, 2008). The challenges faced by the U.S. catfish industry have triggered a desire to analyze and to forecast the impacts of the escalation in feed price and catfish-liked imports on the industry. A thorough analysis of this kind requires knowledge of catfish farm supply. However, estimates of the U.S. catfish farm supply, to date, are inconsistent, unreliable, and in most cases generate insignificant and unstable coefficients (Kinnucan and Sullivan, 1986; Zidack, Kinnucan, and Hatch, 1992; Kouka and Engle, 1998). Therefore, this chapter aims to provide a timely, comprehensive and rigorous estimation of the U.S. catfish farm supply.

Several approaches are employed to estimate agricultural supply, such as linear programming, duality approach, supply system, and reduced-form supply response. However, the supply of a single commodity is often estimated with the duality or supply response approach (Colman, 1983). Relating to the U.S. catfish industry, Kinnucan and Sullivan (1986) computed supply elasticities from production elasticities using a formula suggested by Houck (1985), and found catfish supply elasticities ranging from 1.86 to 8.10. Zidack, Kinnucan, and Hatch (1992) applied a profit function to estimate a U.S. catfish farm supply function, and obtained a supply elasticity of 0.15. They assumed a Cobb-Douglas production function, and that farmers maximize profit based on a ratio of expected product price to expected feed price. Kouka and Engle (1998) estimated catfish supply functions of fingerlings, food-size live catfish, and processed catfish, using the ordinary least squares method. The estimates of catfish supply were mostly statistically insignificant. However, Kouka and Engle used their estimates to compute supply elasticities of 1.41 for fingerling production, 0.14 for food-size farm production, and 0.39 for processed catfish. Neal (2008) estimated simultaneous demand and supply systems at the U.S. catfish farm and wholesale market levels, and obtained short-run and long-run supply elasticities of 0.25 and 0.52 at the farm market, and short-run and long-run supply elasticities of 0.815 and 2.95 at the wholesale market.

The range of supply elasticities is as divergent as the methods used and the measurements used for output and price. The present paper employs both static profit function and adaptive expectation methods to estimate U.S catfish farm supply. Incremental contributions of the paper, considering previous studies, are to first include fixed factors and risk factors in the static supply function; second, to separate the responses of acreage and yield in the dynamic supply response. Therefore, the study allows more flexible and realistic investigations of short-run and long-run behaviors of the U.S. catfish producers. The study has set three objectives: (1) to estimate farm supply functions of the U.S. catfish farm industry; (2) to determine factors affecting the U.S. catfish supply responses to prices and market forces; and (3) to evaluate the risks associated to catfish farm supply. The chapter is organized in the following sections: U.S. catfish farming, conceptual framework, acreage and yield responses, supply response to risk, and summary and conclusion.

2. U.S. Catfish Farming

The U.S. catfish industry developed from a sideline farming activity in the 1970s into a major agricultural industry in the southeastern states of Alabama, Arkansas, Louisiana, and Mississippi (Jolly et al., 2001). The growth of the U.S. catfish farm industry has gone through three periods; the first period was from 1970s to 1980s with an annual growth rate of 23% in sale volume; the second period was from 1990s up to 2003 with a lower annual growth rate of 6%; and the third period is from 2003 to the present with a negative growth rate. In the past, growth in the U.S. catfish industry was mainly derived from expansion of pond acres, technological innovations, marketing efforts, and increasing consumer demand (Jolly et al., 2001).

In the early years, catfish was mainly raised in single-batch production ponds, where fingerlings or stockers were stocked in spring and harvested in fall when fish reached 1.0 to 2.0 pounds in weight. In the mid-1970s, expansions of markets and catfish processing plants required a year-round supply of food-size catfish. Hence, the multi-batch system was developed to stock different sizes of catfish in the same pond, which ensures the availability of food-size fish throughout the year. Multiple-batch systems helped to reduce risk, but its income expectation decreased by 8% to 35% (Engle and

Pounds, 1994). In terms of market outlets, 85% of food-size catfish are sold to processors; the rest are sold to local markets as fresh fish, or to recreational fishing outlets.

The industry is facing major problems of increasing costs and low prices in spite of changes in production that have taken place in recent years. Attempts made to study current shocks on the industry were limited due to lack of reliable estimations of supply functions. In this paper, we intend to examine the supply function taking into consideration the static and dynamic aspects of supply function previously considered only in agricultural crop production.

3. Conceptual Framework

Production economic theory assumes that firms maximize both short- and long-run profits. The production function of single product and multiple inputs is defined as:

$$(1) \qquad Q = F(X_1, X_2 \ldots X_n; Z_1, Z_2 \ldots Z_m)$$

where, Q is single output, Xs are variable inputs, Zs are fixed inputs. The short-run profit is equal to revenue minus variable costs:

$$(2) \qquad \pi = pF(X_1, X_2 \ldots X_n; Z_1, Z_2 \ldots Z_m) - \sum w_i X_i$$

where, p is product price, w_i is input price of the i^{th} input. The normalized profit function was first mentioned by Jorgenson and Lau (1974), and proved more convenient to manipulate through empirical analysis. The normalized profit function is obtained by dividing the profit equation (2) by product price (p):

(3) $\pi/p = F(X_1, X_2 \ldots X_n; Z_1, Z_2 \ldots Z_m) - \sum(w_i/p)X_i$

Firms maximize short-run profit by choosing the optimal levels of variable inputs, $X^*_i = X^*_i(w_1/p, w_2/p, \ldots w_n/p; Z_1, Z_2, \ldots Z_m)$, taking p, w, and Z as given in the situations of competitive factor and product markets. The indirect normalized profit function is obtained by substituting factor demand X^*_i into (3):

(4) $\pi^*(w^*_1, w^*_2 \ldots w^*_n; Z_1, Z_2 \ldots Z_m) = F(X^*_1, X^*_2 \ldots X^*_n; Z_1, Z_2 \ldots Z_m) - \sum w^*_i X^*_i$

where, $\pi^* = \pi/p$ is the normalized profit function, $w^*_i = w_i/p$ is normalized price of input X_i. The output supply is derived from (4) as:

(5) $Q = \pi^*(w^*_1, w^*_2 \ldots w^*_n; Z_1, Z_2 \ldots Z_m) + \sum w^*_i X^*_i$

Yotopoulos and Lau (1979) considered a Cobb-Douglas production function, and derived a normalized profit function as in (4), which has a log-linear functional form:

(6) $\ln\pi^* = a + \sum\alpha_i \ln w^*_i + \sum\beta_j \ln Z_j$

From (6) $\partial\ln\pi^*/\partial w^*_i = \alpha_i/w^*_i$. Equally, $\partial\pi^*/\partial w^*_i = \pi^*\alpha_i/w^*_i$ because $\partial\ln\pi^* = \partial\pi^*/\pi^*$. Shephard's lemma gives $\partial\pi^*/\partial w^*_i = - X^*_i$. Therefore, $X^*_i = - \pi^*\alpha_i/w^*_i$. Substituting the result for X^*_i into (5) we obtain the output supply function:

(7) $Q = \pi^*(\mathbf{w}^*, \mathbf{Z}) - \sum\alpha_i \pi^*(\mathbf{w}^*, \mathbf{Z}) = (1 - \sum\alpha_i)\, \pi^*(\mathbf{w}^*, \mathbf{Z})$

where, **w*** and **Z** are vectors of normalized input prices and fixed factors. Taking the logarithm of both sides of (7) gives a log-linear supply function:

$$(8) \qquad \ln Q = \ln(1 - \sum\alpha_i) + a + \sum\alpha_i \ln w^*_i + \sum\beta_j \ln Z_j$$

The supply function has two properties - homogeneity and symmetry. The specification of the supply function in (8) has a strict constraint that the sum of supply elasticities, with respect to input and output prices, is zero. Own price supply elasticity is $E_s = \partial \ln Q/\partial \ln p = - \sum\alpha_i$. Supply elasticity with respect to price of input i^{th} (X_i) is $E_i = \partial \ln Q/\partial \ln w_i = \alpha_i$. The homogeneity characteristic of the profit function is binding when $E_s + \sum E_i = 0$. If the production function exhibits constant returns to scale (CRTS), the supply function is homogenous to the degree one of fixed factors, or $\sum\beta_j = 1$.

3.1. Technological Change

In general, technical changes cause production output to increase when using the same levels of variable and fixed inputs. Fuss and McFadden (1978) include the technical change factor in the production function as:

$$(9) \qquad Q = F(\mathbf{X}, \mathbf{Z}, t)$$

where, **X** and **Z** are vectors of variable and fixed inputs. Since technical change happens over the long-run, fixed inputs can be considered variable. The letter t represents technical change, and $\partial F/\partial(t) > 0$. By duality, $\partial F/\partial(t) = \partial \pi^*/\partial(t)$, hence technical change has a positive effect on normalized profit function, $\partial \pi^*/\partial(t) > 0$ (Lau, 1978). Technical change can be factor- augmenting and/or output-augmenting. The production function is then specified as:

$$(10) \qquad Q = A(t)\, F\{A_1(t)X_1, A_2(t)X_2, ...A_n(t)X_n; Z_1, Z_2, \ldots Z_m\}$$

where, $A(t)$ is output-augmenting technical change, $A_i(t)$ is factor-augmenting technical change for input X_i. According to Lau (1978), the corresponding normalized profit function is:

$$\pi^* = A(t)\pi\{w^*_1A(t)/A_1(t),\ w^*_2A(t)/A_2(t),\ldots\ w^*_nA(t)/A_n(t);\ Z_1,\ Z_2,\ldots Z_m\} \tag{11}$$

Assuming a Cobb-Douglas production function in the U.S. catfish industry leads to a Cobb-Douglas normalized profit function:

$$\pi^* = A(t)\{w^*_1A(t)/A_1(t)\}^{\alpha 1}\{w^*_2A(t)/A_2(t)\}^{\alpha 2}\ldots\{w^*_nA(t)/A_n(t)\}^{\alpha n}Z_1^{\beta 1}\ Z_1^{\beta 2}\ldots Z_m^{\beta m} \tag{12}$$

Taking the logarithm of both sides of the profit function, we obtain a log-linear normalized profit function with factor- and output-augmenting technical change:

$$\ln\pi^* = \ln A(t) + \sum\alpha_i\ln A(t) - \sum\alpha_i\ln A_i(t) + \sum\alpha_i\ln w^*_i + \sum\beta_j\ln Z_j \tag{13}$$

From (13) and (7), we can obtain the output supply function with technical change in the log-linear functional form as:

$$\ln Q = \ln(1 - \sum\alpha_i) + \ln A(t) + \sum\alpha_i\ln A(t) - \sum\alpha_i\ln A_i(t) + \sum\alpha_i\ln w^*_i + \sum\beta_j\ln Z_j \tag{14}$$

There are a number of ways to measure technical change, for example, time variable is used to indicate a general evolution of technology, dummy variable is employed for a specific known technology, research and extension expenditures can be used as proxies for technical change.

3.2. Short-run vs. Long-run Supply

In the short-run, there is at least one fixed factor in the production process, and producers can adjust only variable inputs to maximize short-run profit. In the long-run, all inputs are variable, and producers can adjust all inputs to maximize long-run profit. Within the time span of a production cycle, variable inputs are feed, fuel, labor, and management. Beyond the span of one production cycle, fingerlings and pond acreage can be variable. Similarly, other fixed factors such as buildings, trucks, and machines can be altered beyond a certain time period, for example, three years or five years. The research hypothesis is that producers respond greater to price incentives over the long-run because more production constraints are eliminated in the long-run. Sadoulet and de Janvry (1995) describe a supply model with consideration of fixed factors in a system of equations:

$$
\begin{aligned}
(15) \qquad & Q = Q(P, k, k^*, t) \\
& k = k(P, k^*, t) \\
& k^* = k^*(P, G)
\end{aligned}
$$

where, Q is farm supply; P is the price vector; k is farm fixed factors, such as water acres, machinery and building; k* is public fixed factor, such as extension service, road, communication, irrigation, and electricity system; and t and G are exogenous factors, such as weather and government programs; farm fixed factors (k), response to price incentives (P), public fixed factors (k*), and exogenous factors (t). Public fixed factors (k*) vary in response to price incentives (P) and government programs (G). Short-run supply elasticity is $E_{SS} = (\partial Q/\partial P)*(P/Q)$, and long-run supply elasticity is $E_{LS} = (\partial Q/\partial P)*(P/Q) + (\partial Q/\partial k)*(k/Q)*\{(\partial k/\partial P)*(P/k) + (\partial k/\partial k^*)*(k^*/k)\} + (\partial Q/\partial k^*)*(k^*/Q)*\{(\partial k^*/\partial P)*(P/k^*)$.

3.3. Empirical Estimation

The empirical model is developed based on the theoretical supply model in (14). Since there is no information about a specific technical change, only output-augmenting technical change is captured through the time variable. Since data on specific fixed factors are unavailable, farm size is employed as a proxy for all fixed factors. Farm size is a good indication of fixed factors because larger farms are likely to have larger fixed capital investments. The present study does not consider public fixed factors in empirical estimation. Hence the empirical models are:

$$\text{(16)} \quad \ln Farmvolume_t = \ln(1 - \alpha_1 - \alpha_2 - \alpha_3 - \alpha_4) + \alpha_0\,Year + \alpha_1 \ln Feedprice_t^* + \alpha_2 \ln Gasprice_t^* + \alpha_3 \ln Capitalprice_t^* + \alpha_4 \ln Wage_t^* + \beta \ln Farmsize_t + \mu_t$$

$$\text{(17)} \quad \ln Farmsize_t = \gamma_0 + \gamma_1\, lag_{12}(\ln Feedprice_t^*) + \gamma_2\, lag_{12}(\ln Gasprice_t^*) + \gamma_3\, lag_{12}(\ln Capitalprice_t^*) + \gamma_4\, lag_{12}(\ln Wage_t^*) + \gamma_5\, Year + \varepsilon_t$$

where, ln stands for the logarithm operator, $Farmvolume_t$ is live catfish volume sold to processors at time t, $Feedprice_t^*$ = feed price/catfish farm price, is normalized catfish feed price at time t, $Gasprice_t^*$ = gas price/catfish farm price, is normalized gasoline price at time t, $Capitalprice_t^*$ = U.S. bank prime rate/catfish farm price, is normalized U.S.

bank prime rate at time t, $Wage_t^*$ = wage/catfish farm price, is normalized U.S. farm wage rate per hour at time t, and $Farmsize_t$ = total pond acre/number of catfish farm, is the average pond acreage per farm at time t.

The system of equations (16) and (17) models the producers' behavior on how much they are willing to supply to the processors at current profitability level, technology level, and at given fixed factors. In the above system, Farmvolume and Farmsize are two endogenous variables. However, the system of (16) and (17) is a recursive system. Therefore, there is no correlation between independent variables and the error term in the individual equations and the equations in the system can be estimated separately without a problem of simultaneous bias. The equation (16) has no intercept since the underlying production function is assumed in the Cobb-Douglas function form and the intercept is represented technology, which is replaced by the time variable (Year). The equation (16) is estimated using non-linear in parameter estimation method. The equation (17) models the producers' behavior in adjusting fixed factors in response to profitability levels. Adjustment of fixed factors requires time, and is often happened at the beginning of a production cycle. Therefore, we use lag 12 normalized input prices to predict how producers adjust fixed factors in response to profit incentives. Since, data are monthly; each equation of (16) and (17) will include eleven dummy variables for the first eleven months in the year to account for seasonal effects in the data.

Data are monthly, available from January 1988 to December 2008. Data on catfish farm volume and farm price are collected from various catfish production reports of the National Agricultural Statistics Service (NASS, 1988-2009); feed price is extracted from the 2008 U.S. Catfish Database by Hanson and Sites (2009); data on U.S. farm wage rate are from USDA database; data on gasoline price are from the Bureau of Labor Statistics (BLS); bank prime rate is collected from the Federal Reserve Bank.

The ordinary least squares (OLS) estimation method can be used to for a recursive system of equations, such as (16) and (17) (Gujarati, 2002). Since (16) is non-linear in parameters, the non-linear least squares (NLS) estimation method should be plausible for the U.S. catfish supply system. The best empirical estimation results of (16) and (17) are presented in Table 1a. The U.S. catfish farm supply equation has expected signs and statistically significant in all of its parameter estimates. Input prices all have negative effects on catfish farm supply. Time trend and farm size both have positive effects on catfish farm supply. Parameter estimate of normalized feed price has a t-value of -2.38, and is statistically significant at 5%. Similarly, parameter estimates of normalized gas price and normalized capital price are significant at 10% and 1%, respectively. The results in Table 1a show that a 1% increase in the feed price, gas price, and capital price causes catfish farm supply to decrease 0.1 %, 0.05%, and 0.15 %, respectively. Supply elasticity is equal to the sum of absolute values of the coefficient of normalized input prices, which is 0.3. In the short-run, the price elasticity of catfish supply is inelastic, and a 1% increase in farm out price will cause catfish farm supply to increase by 0.3 %.

Positive effect of the time trend in supply equation shows that there is technological improvement over time that causes the increase in catfish farm supply, given inputs remain unchanged. However, only 9.8% out of a total increase of 72.68% of the U.S. catfish production between 1988 and 2008 is attributed to technical change. The rest of the increase in U.S. farm catfish production can be attributed to the increase in variable and fixed factors, such as feed, ponds, machinery, and other factors of production. Farm size, a proxy for farm's fixed factors, has a positive effect on catfish supply as expected. Wald test rejects the null hypothesis that Farmsize's coefficient equals to 1. The test result reveals that the U.S. catfish farm production is in the stage of decreasing returns to scale, since $\beta = 0.39$, smaller than one.

Farm size is significantly responding to price incentives. Producers consider the expected profitability in making decisions on farm investment. The expected profitability is simply formulated by a ratio of expected input price over expected output price. The empirical estimation of the farm size equation shows that only feed price has significant, negative effect on farm size, as expected, with t value of -5.73. Gas price does not have a significant effect on farm size. The time trend has a positive effect on farm size. The estimation confirms that lower expected profitability will discourage producers to invest in fixed factors. Consideration the effect of fixed factors on farm supply will give us the long-run supply behavior of the producers. Long-run catfish farm supply elasticity is computed using formulas derived from (15), obtaining the long-run supply elasticity of 0.45.

The empirical NLS estimations of (16) and (17) give plausible results as discussed above. The estimations have good fit with adjusted R squares of 0.78 and 0.80 for farm supply and farm size equations. However, White test and Durbin-Watson statistics indicate problems of heteroscedasticity and autocorrelation in both empirical equations (Table 1a). In addition, Shapiro-Wilk normality tests shows that both empirical models have non-normally distributed error terms. The least squares method in the presence of heteroscedasticity and autocorrelation still give unbiased and consistent estimate, but inefficient estimates. This means that standard errors of parameter estimates are miscomputed, and we cannot believe in the t tests for the significance of parameter estimates in the empirical equations of (16) and (17), Table 1a.

The problem of heteroscedasticity and autocorrelation in the least squares estimation was addressed by Newey and West (1987), using the generalized method of moments (GMM) techniques developed by Hansen (1982) to suggests a class of consistent estimators that involve calculating weighted sum of estimated autocovariances of cross-products of instruments and residuals. Newey and West (1994), discussed further about the method to identify the lag length selection in the estimation of heteroscedasticity and autocorrelation consistent covariance matrix (HACCM). The formula of lag length of autocovariance employed in this study is $l(n) = 3(T/100)^{2/9}$, where T is the number of observation in the time series data. The Newey-West heteroscedasticity and autocorrelation consistent covariance matrix (HACCM) estimations of the system of equation 916) and (17) are presented in Table 1b. The results from GMM estimation are similar to that in NLS estimation method. The t values in the GMM method are generally smaller than those in NLS method. In the farm supply equation, gas price becomes statistically insignificant, while feed price and capital price (interest rate) are still significant. The farm supply elasticity is equal to absolute value of coefficients of feed price and interest rate, 0.252. The time trend and farm size both still have positive effect on farm supply as in NLS method. In the farm size equation, the sign of interest turns into negative as expected, however, still insignificant. Normalized feed price has significant negative effect on farm size. A 1% increase in normalized feed price in the previous year will cause producers to reduce the farm size by 0.56 %. Therefore, the total effect of farm price on farm supply will include the effect of farm price through normalized input price in supply equation, and the effect of farm price though farm size from farm size equation. The long-run supply elasticity is computed using formula derived from (15), and equal to 0.47.

4. Acreage and Yield Responses

In the literature, models have been developed to explain the dynamics of agricultural supply, such as the adaptive expectation model (Nerlove, 1958) and partial adjustment model (Griliches, 1967), and both models lead to a lag distributed model. The basic foundation of distributed lag models of agricultural supply is that farm producers make decisions based on past prices. Recently, Vector Autoregressive (VAR) models have been developed to explain the dynamics of market behavior (Bessler, 1984; Brandt and Bessler, 1984). In addition, the dynamics of supply can be more precisely investigated when considering biological characteristics of plants and animals in the estimations. Chavas and Johnson (1982) separated U.S. broilers and turkey production into 4 stages from placement, testing, hatching, and production. Holt and Johnson (1988) also investigated supply dynamics of different production stages in the U.S. hog industry.

Catfish ponds cannot be easily transformed into other crop activities without disturbing its immediate production. In catfish farming, the numbers of pond acres put into production are decided in advance of stocking time. Therefore, catfish pond acreage is fixed in the short-run, meaning that producers cannot adjust production acreage in response to immediate changes in prices. However, catfish producers can adjust other variable inputs, such as feed, labor, management, water, and energy in response to immediate changes in prices. The short-run adjustment affects production yield. In other words, producers adjust production yield to maximize short-run profit, and adjust production acres to maximize long-run profit.

Production output volume is equal to production acres multiplied by yield, $Q = A_0*Y$. Therefore, the percentage change in output (dlnQ) is equal to the sum of percentage change in acreage (dlnA) and percentage change in yield (dlnY), $dlnQ = dlnA + dlnY$. Dividing by the percentage change in output price (dlnp) obtains $dlnQ/dlnp = dlnA/dlnp + dlnY/dlnp$, or $E_Q = E_A + E_Y$, where E_Q is catfish farm supply elasticity, E_A is catfish acreage elasticity with respect to output price, and E_Y is catfish yield elasticity with respect to output price. In the short-run, E_Y is larger than E_A. In other words, catfish yield is more responsive to price changes than catfish acreage in the short-run, or $E_Q > E_Y > E_A$. However, catfish yield has an upper bound at a certain time due to technological constraints. Therefore, yield should respond to prices less than acres do in the long-run, or $E_Y < E_A$ in the long-run.

4.1. Nerlovian Acreage Response

The Nerlove model assumes that farmers make decisions primarily based on price expectations, and through a partial adjustment of output (Nerlove, 1956, 1958). A prominent question in empirical estimation is what price should be used in model estimation. In the literature, price series frequently used are crop prices actually received by farmers; ratio of crop price over some consumer price index; ratio of crop price over some input price index; and ratio of crop price to some index of price of competitive crops (Askari and Cummings, 1977). Output measurements are incorporated into supply response estimation in various ways, but mostly as crop weight or volume. However, acreage is a good measurement relating producers' expected price to their production decision. The time lag between planting and harvesting is an important factor to the response of output supply to price. The general supply response model is represented as:

(18) $A^*_t = a_0 + a_1 P^*_t + a_2 Z_t + u_t$

(19) $P_t^* - P_{t-1}^* = \beta(P_{t-1} - P_{t-1}^*)$

(20) $A_t - A_{t-1} = \gamma(A^*_t - A_{t-1})$

where A^*_t is desired farm acreage at time t; A_t is actual farm acreage at time t; P_t^* is expected price at time t; P_t is actual price at time t; and Z_t represents exogenous variables at time t. Equation (18) reflects farmers' decisions at the beginning of production based on the expected price. Equations (19) and (20) show the partial adjustment behavior of farmers with respect to stocked acreage and expected price. Elimination of unobserved terms from (18), (19), and (20), we obtain a reduced form of supply response:

(21) $A_t = b_0 + b_1P_{t-1} + b_2A_{t-1} + b_3A_{t-2} + b_4Z_t + b_5Z_{t-1} + v_t$

where, $b_0 = a_0\beta\gamma$, $b_1 = a_1\beta\gamma$, $b_2 = 2 - \beta - \gamma$, $b_3 = -(1 - \beta)(1 - \gamma)$, $b_4 = a_2\gamma$, $b_5 = -a_2(1 - \beta)\gamma$, and $v_t = \gamma u_t - (1 - \beta)\gamma u_{t-1}$. The short-run supply elasticity is $E_{SS} = b_1*(\overline{P}/\overline{Q})$. The long-run supply relationship between output and price is represented by the coefficient a_1 in (19), and is derived from estimates of (21), as $a_1 = b_1/(1 - b_2 - b_3)$. The long-run supply elasticity is $E_{LS} = b_1/(1 - b_2 - b_3)*(\overline{P}/\overline{Q})$.

4.2. Yield Response

The theoretical model was first proposed and discussed by Houck and Gallagher (1976) in their research on price responsiveness of U.S. corn yield. Houck and Gallagher (1976) argue that producers maximize their profit by producing at an output level where marginal physical product is equal to the ratio of output price over input price, given fixed cultivation acres. Therefore, output is a function of price ratio and given acreage:

$$(22) \qquad Q = F(p/w, A_0).$$

where, Q is output, p is output price, w is input price, and A_0 is given acreage in the short-run. Hence, yield (Y) is equal to total output (Q) divided by acreage (A_0). Hence, yield is a function of price ratio and pond acres:

$$(23) \qquad Y = Q/A_0 = F(p/w, A_0)/A_0 = g(p/w, A_0).$$

The variations of catfish yield and price ratio are presented in Figure 1. There are three types of variations in catfish yield. First, catfish yield has a long-run increasing trend over the study period. Second, catfish yield has a medium-run cyclical pattern, going up and down in about every five or six years. Third, catfish yield has a short-run fluctuating pattern. Similarly, the Figure 1 also shows three types of variations in output-input price ratio. The price ratio has a slightly decreasing trend over the long-run.

The long-run increasing trend in catfish yield and decreasing trend in price ratio could be explained by evolution of technology. Production technology is improving over time, shifting catfish supply outward, and reducing relative product price. On the other hand, technological improvements allow producers to increase production yield over time. In the medium-run, the cyclical pattern observed in catfish yield may originate from the fluctuation of relative output price. A higher relative output price means higher profitability, and producers have higher incentive to produce more, to maximize profit by increasing catfish yield in the medium-run. Therefore, the cyclical pattern in yield is similar to that in the price ratio. In the short-run, the fluctuation in catfish yield may be reflected by noted seasonality patterns in catfish production. Even though catfish is harvested year round in the prevailing multi-batch production system, more catfish is harvested in March before releasing new batches of fingerlings, and in October before the temperature goes down during the winter.

4.3. Empirical Estimation

The dynamics of catfish supply can be understood when simultaneously investigating the responsiveness of catfish acreage and yield to price changes. The short- and medium-run response of yield is empirically specified using a method proposed by Houck and Gallagher (1976) as in (23). The long-run adjustment of production acreage is specified from the model developed by Nerlove (1958) as in (21). The system of equations of catfish supply responses is presented below:

(24) $\text{Yield}_{(t)} = a_0 + \sum b_i{*}\text{Priceratio}_{i,t} + a_1{*}\text{Acre}_{(t)} + a_2{*}\text{Year}_{(t)} + u_{(t)}$

(25) $\text{Acre}_t = a_0 + \Sigma\, b_i{*}\text{Priceratio}_{(t-i)} + a_1\text{Acre}_{t-1} + a_2\text{Acre}_{t-2} + a_3 Z_t + a_4 Z_{t-1} + v_t$

where, $Yield_{(t)}$ is catfish yield at time t, $Acre_t$ is catfish acreage at time t, $Priceratio_i$ is the ratio of output price over input prices i^{th} or CPI, and Z_t is a vector of exogenous factors such as weather, partial harvest, seasonality, survival rate, inventories, and number of processing plants. Trend variable (Year) accounts for non-price factors, such as technology and climate change.

Simultaneous estimation of yield and acreage response in (24) and (25) are presented in Table 2. The system of equations of catfish yield and acreage response is estimated employing non-linear Full Information Maximum Likelihood method. The estimation is reliable since both estimated equations have no problems of heteroscedasticity detected through White test, and no autocorrelation problem through Godfrey test. The models have no specification error since the Shapiro-Wilk test shows normally distributed residuals. Adjusted R-squares are high, 0.68 for yield equation, and 0.87 for the acreage response equation. Catfish yield responds instantaneously and positively to output price, as expected. A 1% increase in catfish farm price causes catfish yield to increase by 0.15 %. Input prices negatively affect catfish yield, except for farm wage. Yield has an upward trend over the years due to technological progress. Acreage positively affects catfish yield. However, Acreage squared has a negative effect on yield, as larger acreages require more input, and management skill to maintain yield level.

Catfish acreage dynamics follow the Nerlovian hypothesis. Producers make decisions on catfish acreage based on their expectation about the future price, and allocate catfish production acres through a partial adjustment mechanism. The estimation of the Nerlovian acreage response model is reliable and statistically significant. The corresponding short-run and long-run acreage response elasticities are 0.11 and 0.41.

Therefore, the short-run catfish farm supply elasticity is the sum of yield elasticity and short-run acreage elasticity, equaling to 0.26. In other words, a 1% increase in output price causes catfish farm supply to increase 0.26 % in the short-run. The long-run acreage response to price change is 0.41. Total long-run supply elasticity is computed by the sum of yield elasticity, long-run acreage elasticity, and long-run effects of acreage over yield. Long-run catfish supply elasticity is 2.14.

5. Supply Response to Risks

There are two types of risks in agriculture: production and market risk. Production risk involves the variation of production yield due to variations of physical inputs and uncertainties, such as diseases, natural disasters, and climate conditions. Market risk involves the price, interest, and consumer demand fluctuation and depends on macro-and micro economic conditions (Jolly and Clonts, 1993). Price risk increases with closed and fragmented agricultural markets. Production risk and price risk could be independent or correlated, and influence yield and acreage (Sadoulet and de Janvry, 1995). The traditional approach to modeling producers' behavior under risk is the expected utility approach proposed by Von-Neumann and Morgenstern (1944), and applied by Chavas and Holt (1990) to analyze agriculture supply with risk factors. Households maximize expected utility from their consumption (G):

(26) Max EU(G) s.t. budget constraint

The budget constraint states that all income is spent by the household, or $I + R - C = qG$. Where, I is exogenous income from initial wealth (W_0) and its opportunity cost (r), and I

$= rW_0$; R is production revenue, equal to output price (p) times production output F(X, Z), or R = pF(X, Z); C is production cost, equal to input price (w) times production inputs (X), C = wX; and q is consumer price index. Equation (26) is transformed to:

(27) $\text{Max } EU(r/qW_0 + p/qF(X, Z) - w/qX)$

and the solution for maximized expected utility yields the optimal input demand function, $X^*(p, w, q, r, Z, W_0)$, and the optimal output supply function as:

(28) $Q = F(X^*, Z) = S^*(p, w, q, r, Z, W_0)$

Producers make decisions about supply depending on available information. At the time when production decisions are made, producers are aware of the opportunity cost (r), consumer price index (q), fixed factors (Z), and initial wealth (W_0). Output and input prices are unknown. In addition, some exogenous factors, such as price, sales volume and inventory in the closely-related processing market are known. The underlying hypothesis is that risk in related markets will affect the risk at the farm gate. Those unknown variables to farm decision-making process are considered as stochastic random variables. The distributions of those random variables are well captured by their moments (Pope and Just, 1991). Therefore, farm supply function in the presence of price risk is generalized as:

(29) $Q = S^*(p^e, w^e, p^v, w^v, q, r, Z, W_0)$.

where, p^e is expected output price, w^e is expected input price, p^v is variance of output price, w^v is variance of input price, q is consumer price index (CPI), r is opportunity cost of wealth, W_0 is initial farm wealth, and Z is vector fixed factor, or exogenous factors. The first two moments of random variables are defined by Just (1974) as:

$$E(p) = \theta_p \sum_{k=0}(1 - \theta_p)^k p_{t-k-1}$$

$$V(p) = \delta_p \sum_{k=0}(1 - \delta_p)^k [p_{t-k-1} - E(p_{t-k-1})]^2$$

$$E(w_i) = \theta_{wi} \sum_{k=0}(1 - \theta_{wi})^k w_{i,\, t-k-1}$$

$$V(w_i) = \delta_{wi} \sum_{k=0}(1 - \delta_{wi})^k [w_{i,\, t-k-1} - E(w_{i,\, t-k-1})]^2$$

Empirical models of supply response to risks are specified as linear risk model proposed by Just and Pope (1979), separating effects of independent variables on mean and variances of output supply:

$$(30) \qquad Q = f(p^e, w^e, p^v, w^v, q, r, Z, W_0) + g(p^e, w^e, p^v, w^v, q, r, Z, W_0)*\varepsilon$$

where, ε is a stochastic random error, $E(\varepsilon) = 0$ and $V(\varepsilon) = 1$. The estimation procedure of (30) follows three stages in Just and Pope (1979). The stage I involves the non-linear least squares (NLS) estimation of $Q = f(p^e, w^e, p^v, w^v, q, r, Z, W_0)$ with the estimated residual, ê. The estimated residual (ê) is systematically heteroscedastic, since $\hat{e} = g(p^e, w^e, p^v, w^v, q, r, Z, W_0)*\varepsilon$, or $\ln(|\hat{e}|) = \ln g(p^e, w^e, p^v, w^v, q, r, Z, W_0) + \ln(*\varepsilon)$. The stage II involves the ordinary least squares (OLS) estimation of $\ln(|\hat{e}|) = \ln g(p^e, w^e, p^v, w^v, q, r, Z, W_0) + \ln(*\varepsilon)$, to obtain the estimate of ln(g). The third stage is proceeded by NLS's estimation of equation (30) after it is weighted by ĝ, or $Q/\hat{g} = f(p^e, w^e, p^v, w^v, q, r, Z, W_0)/\hat{g} + \varepsilon$.

The empirical model is estimated in log-linear functional form, and the three stages of estimation of (30) are presented in Table 3a. The results show that catfish farm producers consider the expected profitability and the variance of profitability when making decisions about farm supply production. The results in stage I show that catfish farm supply is positively related to profitability levels, as expected. The expected normalized gas price and expected normalized capital price significantly affect farm supply, while the expected normalized feed price is not statistically significant. The effects of profitability variation on catfish supply are different for different inputs. Variations of feed price and gas price negatively affect farm supply level. In contrast, variation of capital price positively affects farm supply. The plausible explanation is higher risk in fixed investment may force catfish producers to concentrate more on catfish production, which has relatively lower risk than other related business ventures. Time variable and farm size both have positive effects on farm supply, as expected. In the short-run, within 24 months, farm supply elasticity is 0.23 from the estimation of stage I.

In the stage II (Table 3a), the risks or variations of catfish farm supply do not depend on expected means and variations of output and input prices, except for gas price. Gas is the only input affecting the variation in catfish farm supply. Over the years, the variation of catfish farm supply is decreasing. In other words, the U.S. catfish producers learn to reduce their risk over the years, or are risk-averse. The results of stage III (Table 3b) confirm the results in stage I that catfish farm supply is affected by expectations and variations of output and input price, or farm profitability. The catfish farm supply elasticity is 0.59 in the short-run (with 24 months) after removing all risk factors. The result confirms that U.S. catfish producers are risk-averse, in the sense that they respond less to profit in the presence of risks.

6. Summary and Conclusion

The present study uses profit function approach and Nerlove adaptive expectation approach to analyze the U.S. catfish farm supply. The empirical estimations generate similar short-run supply elasticities, 0.23 and 0.28, respectively. However, the long-run supply elasticities are quite different between the two approaches, 0.8 in profit function approach and 2.1 in adaptive expectation approach. Only 8.5% out of 72.7% of the U.S catfish production expansion between 1988 and 2008 is attributed to technical change. The U.S. catfish industry is at the stage of decreasing returns to scale, 1% increase in all input factors causes farm output to increase by 0.34 %. In the short-run, catfish producers mainly vary production yield in response to price changes. In contrast, catfish acreage is more responsive to the price change in the long-run. The risk model in the catfish supply equations shows that variations of profitability negatively affect farm supply. The variations or risks of farm supply are mainly determined by non-price risk factors. The U.S. catfish farm supply variation is decreasing over the years. The U.S. catfish producers respond less to profit incentives in the presence of risk.

Appendix 1

Table 1a. Non-linear Least Squares (NLS) Estimation of U.S. Catfish Farm Supply

U.S. catfish farm supply equation			Farm size equation		
Parameter	Estimate	t Value	Parameter	Estimate	t Value
year	0.004094***	61.89	Constant	-109.705	-25.13
lnfeedprice	-0.10557**	-2.38	lag12(lnfeedprice)	-0.40347***	-5.73
lngasprice	-0.04621*	-1.78	Lag12(lninterest)	0.017408	0.30
lninterest	-0.14995***	-4.98	year	0.057685***	26.01
lnfarmsize	0.379658***	16.37	D1	-0.00657	-0.13
D1	0.13094	4.45	D2	-0.01511	-0.29
D2	0.130895	4.45	D3	-0.02541	-0.49
D3	0.225682	7.66	D4	-0.02736	-0.53
D4	0.097981	3.32	D5	-0.0295	-0.57
D5	0.093389	3.15	D6	-0.02241	-0.43
D6	0.0604	2.04	D7	-0.01109	-0.22
D7	0.088218	3.00	D8	-0.00989	-0.19
D8	0.137277	4.66	D9	-0.0045	-0.09
D9	0.105308	3.57	D10	-0.00549	-0.11
D10	0.160677	5.45	D11	-0.00288	-0.06
D11	0.051643	1.76			
R^2-adjusted	0.7826		R^2-adjusted	0.8054	
DW	0.2155		DW	0.0371	
White test	p=<.0001		White test	p=<.0001	
Normality test	p=<.0001		Normality test	p=<.0001	

Note: at the estimates, *** means significant at 99%; ** significant at 95%; * significant at 90%

Table 1b. Generalized Method of Moments (GMM) Estimation of U.S. Catfish Farm Supply

U.S. catfish farm supply equation			Farm size equation		
Parameter	Estimate	t Value	Parameter	Estimate	t Value
year	0.004104***	31.87	Constant	-112.812	-7.65
lnfeedprice	-0.12212*	-1.84	lag12(lnfeedprice)	-0.55702***	-2.66
lngasprice	-0.01326	-0.27	Lag12(lninterest)	-0.17129	-0.56
lninterest	-0.13**	-2.00	year	0.059105***	7.75
lnfarmsize	0.389913***	11.34	D1	0.008737	0.25
D1	0.128973	5.12	D2	-0.00976	-0.21
D2	0.129629	4.43	D3	-0.0396	-0.66
D3	0.229809	6.97	D4	-0.05242	-0.80
D4	0.102135	2.89	D5	-0.05635	-0.88
D5	0.10717	3.25	D6	-0.04522	-0.75
D6	0.068375	2.14	D7	-0.01887	-0.34
D7	0.092455	3.03	D8	-0.01401	-0.26
D8	0.142653	4.67	D9	-0.01159	-0.23
D9	0.108008	3.62	D10	-0.00724	-0.18
D10	0.15958	6.41	D11	-0.0011	-0.04
D11	0.055981	2.91			
R^2-adjusted	0.7777		R2-adjusted	0.7782	
DW	0.2108		DW	0.0461	
White test	p=<.0001		White test	p=<.0001	
Normality test	p=<.0001		Normality test	p=<.0001	

Note: at the estimates, *** means significant at 99%; ** significant at 95%; * significant at 90%

Table 2a. FIML Estimation of Yield and Acre Response

U.S. catfish yield response (lnYield)			Catfish acres response (Acre)		
Variable	Estimate	t-value	Variable	Estimate	t-value
Constant	-27.2582	-1.16	Constant	-1.04E+07	-7.8
log(Farmprice)	0.148869*	1.69	lag12(Priceratio)	58795.94***	8.16
log(Feedprice)	-0.06544	-1.03	lag12(Acre)	0.976636***	14.32
log(Gasprice)	-0.11184**	-2.82	lag24(Acre)	-0.25419***	-4.02
log(Interest)	-0.07639*	-1.94	Year	5306.216***	7.81
log(Wage)	0.508934	1.51	CPI	-1303.15***	-8.66
Acre	0.000025**	2.46			
Acre^2	-7.27E-11**	-2.34			
Year	0.011634	0.95			
R^2- adjusted = 0.68			R^2- adjusted = 0.87		
DW = 0.8547			DW = 0.3705		
White's Test: p-value = <.0001			White's Test: p-value= <.0001		
Godfrey Test: p-value = <.0001			Godfrey Test: p-value = < 0.0001		
Shapiro-Wilk: p-value = 0.7233			Shapiro-Wilk: p-value = 0.2403		

Note: at the estimates, *** means significant at 99%; ** significant at 95%; * significant at 90%

Table 2b. GMM Estimation of Yield and Acre Response

U.S. catfish yield response (lnYield)			Catfish acres response (Acre)		
Variable	Estimate	t-value	Variable	Estimate	t-value
Constant	56.7968	0.45	Constant	-9448845	-4.08
log(Farmprice)	0.981267	1.31	lag12(Priceratio)	114487.6***	5.08
log(Feedprice)	0.093071	0.23	lag12(Acre)	1.043329***	9.21
log(Gasprice)	0.241399	0.71	lag24(Acre)	-0.29549*	-1.94
log(Interest)	-0.32317**	-2.16	Year	4827.123***	4.07
log(Wage)	0.807442	0.7	CPI	-1152.57***	-4.53
Acre	6.99E-06	0.14			
Acre^2	1.76E-11	0.1			
Year	-0.03334	-0.5			
R2- adjusted = 0.2226			R2- adjusted = 0.8251		
DW = 0.4961			DW = 0.3131		
White's Test: p-value = <.0001			White's Test: p-value= <.0001		
Godfrey Test: p-value = <.0001			Godfrey Test: p-value = < 0.0001		
Shapiro-Wilk: p-value = 0.2567			Shapiro-Wilk: p-value = 0.5124		

Note: at the estimates, ***means significant at 99%; **significant at 95%; *significant at 90%

Table 2c. Estimates of Farm Supply Elasticities

Elasticities	FIML	GMM
Yield elasticity	0.148869	0.981268
Short-run acre elasticity	0.110681	0.215517
Long-run acre elasticity	0.398767	0.854675
Short-run elasticity	0.259549	1.196785
Long-run elasticity	0.547436	1.835943

Table 3a. **Price Risk in the Estimation of U.S. Catfish Farm Supply (Stages I and II)**

Stage I: (lnFarmvolume)			Stage II: (log(square of residual from stage I)		
Parameter	Estimate	t-value	Parameter	Estimate	t-value
year	0.004141***	46.64	year	-0.00465***	-2.32
lnerFeedprice	0.051493	0.81	lnerFeedprice	1.198074	0.91
lnerGasprice	-0.11529***	-3.65	lnerGasprice	-1.31401	-1.27
lnerInterest	-0.11354***	-3.12	lnerInterest	-0.37562	-0.48
lnevrFeedprice	-0.03548***	-3.16	lnevrFeedprice	-0.32978	-1.44
lnevrGasprice	-0.00071	-0.09	lnevrGasprice	0.397686*	1.7
lnevrInterest	0.041329***	4.22	lnevrInterest	-0.22645	-1.08
lnFarmsize	0.459938***	12.9	lnFarmsize	-0.13669	-0.2
R^2-adjusted = 0.6904			R^2-adjusted = 0.0271		
DW = 0.6797			DW = 1.982		
White's Test = 178.7; p-value = <.0001			White's Test = 56.95; p-value = 0.0753		
Godfrey: p-value = <.0001			Godfrey Test: p-value = 0.94		
Shapiro-Wilk: P-value = 0.0471			Shapiro-Wilk: p-value = <.0001		

Note: at the estimates, *** means significant at 99%; ** significant at 95%; * significant at 90%

Table 3b. Price Risk in the Estimation of U.S. Catfish Farm Supply (Stage III)

Stage III: (weighted lnFarmvolume)		
Parameter	Estimate	t-value
year	-0.0007***	-20.01
lnerFeedprice	1.187334***	19.94
lnerGasprice	-1.33812***	-33.05
lnerInterest	-0.43556***	-11.56
lnevrFeedprice	-0.34562***	-31.46
lnevrGasprice	0.358493***	24.92
lnevrInterest	-0.16474***	-14.86
lnFarmsize	0.299583***	7.26
R^2-adjusted = 0.9778		
DW = 0.6555		
Godfrey Test: LM = 98.22; p-value = <.0001		
White's Test: 194.6; p-value = <.0001		
Shapiro-Wilk: p-value = 0.0004		

Note: at the estimates, *** means significant at 99%; ** significant at 95%; * significant at 90%

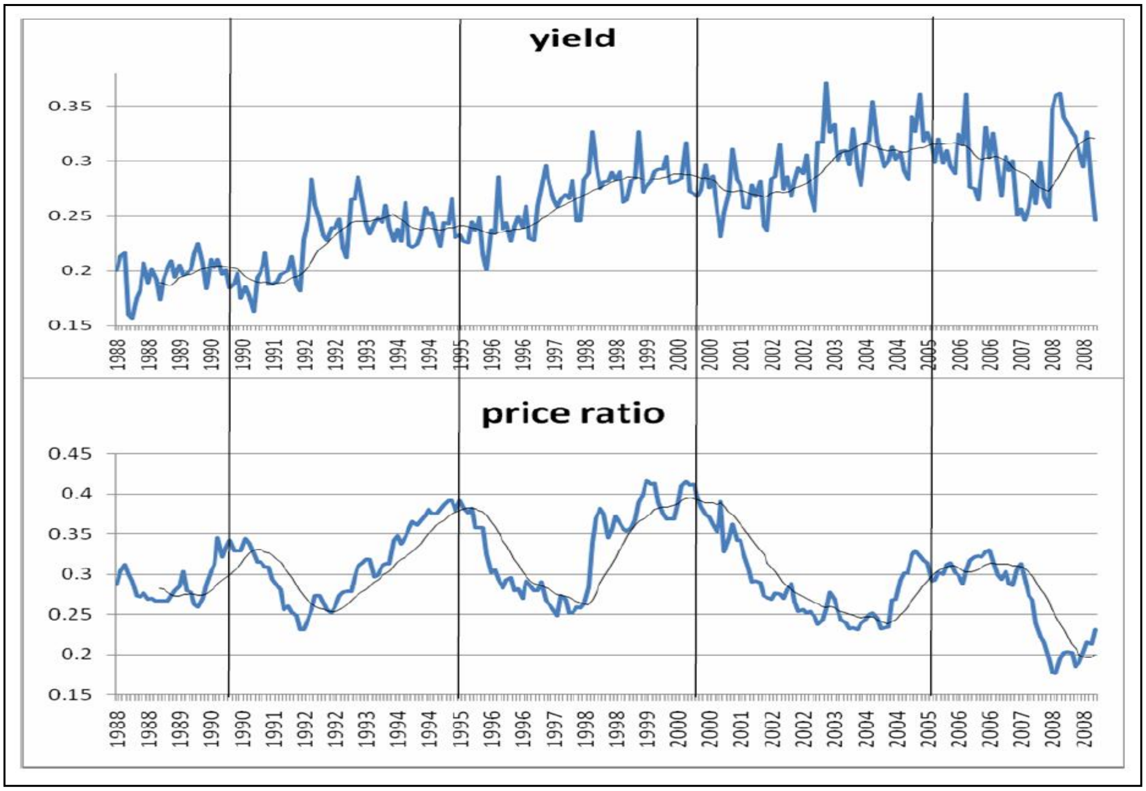

Figure 1. **U.S. Catfish Yield and Output-feed Price Ratio Variation During 1988-2008**

CHAPTER 2: ASYMMETRIC PRICE TRANSMISSION AND MARKET POWER IN THE U.S. CATFISH INDUSTRY

1. Introduction

Price is the primary mechanism by which markets are linked, and vertical transmission of a price shock is an important element in the description of a market operation (Goodwin and Holt, 1999). However, price transmission may not always be symmetric. Peltzman (2000) found that asymmetry in price transmission is prevalent. Most studies refer to non-competitive market structure as a main reason for asymmetric price transmission (Meyer and Von Cramon-Taubadel, 2004). However, Weldegebriel (2004) argued that oligopoly and oligopsony power are not necessarily the cause of asymmetric price transmission with the degree of price transmission as a benchmark in a perfectly competitive market. Empirical tests on the link between asymmetric price transmission and market power are limited, and produce mixed results partially due to difficulties in finding an appropriate proxy for market power (Meyer and Von Cramon-Taubadel, 2004). The present study investigates the nature of price transmission between the U.S. catfish farm and wholesale markets, and the linkages between market power and the transmission of prices. The study also examines the welfare distribution effect associated with asymmetric price transmission and market power.

Numerous studies have examined vertical price transmission in the U.S. catfish industry (Kinnucan and Sullivan, 1986; Kinnucan and Wineholt, 1988; Nyankori, 1991; Zidack et al, 1992; Hudson; 1998; Hudson and Hanson, 1999; Buguk, Hudson and Hanson 2003; Kinnucan and Miao, 1999). Those studies found transmissions from farm to wholesale prices. The magnitude of price transmission elasticities vary across studies, 0.29 in Kinnucan and Wineholt (1988), 0.68 in Zidack et al (1992), 0.41 in Kinnucan (1995), 0.64 in Kinnucan and Thomas (1997), 0.63 in Kinnucan and Miao (1999), and 0.29 in Kinnucan, Sindelar and Hatch (1988). However, none of the previous studies tested asymmetry in price transmission, as well as correcting the possible non-stationary problem when dealing with time series in their tests of price transmission.

The literature about market power in U.S. catfish processing industry is mixed. Kouka (1995) developed a model to measure the conjectural elasticities and oligopolistic power, and found evidence of oligopolistic power and some degree of price enhancement. Hudson (1998) tested imperfect competition in the U.S. catfish market using conjectural variation, and concluded that the U.S. catfish market is competitive. Hudson and Hanson (1999) analyzed marketing margins using the number of processing plants as a proxy for market concentration, and found that the number of processing plants has no effect on farm-wholesale price spread. Bouras and Engle (2007) found oligopoly power index of 0.28, and oligopsony power index of 0.68 with a conjectural elasticity of 0.073, but the estimates of market power are statistically insignificant.

The present literature on price transmission in the U.S. catfish market has left the following unresolved questions: first, is there asymmetry in price transmission between farm and wholesale markets in the U.S. catfish industry? Second, what are the factors attributable to asymmetric price transmission in the industry, if present? Lastly, who gains and who loses from the asymmetric price transmission in the U.S. catfish industry?

The present study's objectives are: (1) test the asymmetry in price transmission between farm price to wholesale price; (2) test the linkage between market power and price transmission in the U.S. catfish processing sector; (3) investigate the welfare distribution between producers, processors, and consumers in the presence of asymmetric price transmission and market power in the U.S. catfish industry. The paper will be organized into the following sections: structure of the U.S. catfish industry, theoretical model, empirical estimation and results, welfare distribution, and summary and conclusion.

2. Structure of the U.S. Catfish Industry

Some elements of market concentration may be detected in the U.S. catfish processing sector as the number of processors is relatively small compared to the number of catfish growers. Catfish processing was substantially concentrated in the 1970s with the four-firm industry concentration ratio being 98% in 1979 (Miller, 1981). During 1980s the number of catfish processing plants increased rapidly from about 10 plants to the largest number of 37 plants in 1990. Since then, the number of catfish processors has been decreasing, remaining at about 20 in 2008. Dillard (1995) estimated the catfish processing four-firm industry concentration ratio at 60-70% by 1995. Masuda (2002) computed the four-firm industry concentration ratio of catfish processing of 52%.

About 85% of total live catfish are sold to processors. Processors buy live catfish and process fish into whole fish, fillet, nugget, and steak forms. Whole dressed fish, which are gutted and skinned, are frozen or consumed immediately as fresh products. Further processing involves filleting and cuttings as steak and nugget forms. Fillet processing technology has gone through significant improvements during early 1990. In contrast, technical change in whole fish processing has not changed as fast (Hudson and Hanson, 1999).

Quality of live catfish begins to deteriorate soon after harvest. Live catfish are often processed within 30 minutes after leaving farmers' pond (Masuda, 2002). The distance between catfish ponds and processors should not be too far in order to keep transportation cost low and maintain fish quality for processing. Therefore, a processor may have a certain market power over catfish growers within neighboring areas.

Vertical integration of industries reduces transaction costs, results in higher quality, and lowers price to consumers. In the U.S. catfish industry, vertical integration was developed in various forms, such as "grower-owned processor", "cooperative processor", and "independent processor". The "grower-owned processors" have the highest level of association between catfish grower and processors. The "cooperative processors" include catfish growers among many groups of people who have ownership over the processing plants shares. The "independent processors" are more loosely vertically integrated with catfish growers, but often develop some association with growers, such as purchase contracts, fingerling and feed assistance, "delivery right" to buy a certain volume of live fish regardless of market condition (Masuda, 2002). The vertical integration helps processors gain oligopolistic power over consumers (Naynkori, 1991).

There is a close relationship between farm price and wholesale price (Figure 1). However, the wholesale-farm price margin in real term has been decreasing over time (Figure 2). The margin is the gross revenue per unit of output of the processing industry; hence decreasing industry's margin suggests one of, or a combination of, the following factors faced by the U.S. catfish processors: higher competitive markets; improving efficiencies; and decreasing input price. But, Figure 3 shows increasing trends in real wage and real energy price, and only capital price has been declining over time. Therefore, catfish processors may employ more capital/machines intensive technology to save labor and energy costs. As a result, the capacity of processors is increasing and the number of processors is decreasing (Figure 4a, 4b) leading to increasing in market power of processors over growers.

Market power of an industry is related to the ability to gain extra-profit from charging higher market prices to consumers, and paying lower market prices to input suppliers. There is some evidence of market power in the U.S. catfish processing (Kinnucan and Sullivan, 1986; Kouka, 1995; and Bouras and Engle, 2007). Recently, catfish imports have been increasing faster, and could be a countering factor to the oligopoly market power of the U.S. catfish processors.

3. Theoretical Model

Gardner (1975) developed a model to link output market with farm input market, and non-farm input markets to explore the nature of farm-retail price spread in competitive markets. Gardner (1975) found that elasticities of farm-retail price transmission are different when market shocks are stimulated from different sources, such as a shift of food demand, a shift of farm supply, or a shift of marketing input supply. Holloway (1991) extended Gardner's model to include oligopoly power in the food processing sector. Azzam (1998) extended Gardner's model to include oligopsony power in the food processing sector. Weldegebriel (2004) developed a theoretical model with oligopoly and oligopsony market power to predict price transmission deviations from that in competitive market situations. Weldegebriel found that asymmetric price transmission exists in competitive markets, and market power does not necessarily lead to imperfect price transmission. Peltzman (2000) empirically found asymmetric price transmission in competitive markets.

Firm pricing behavior will influence the level of profit extracted by market participants at various stages of marketing. The levels of profit and market behavior can provide information on market structure and price transmission. Hence, we will examine both market structure and price transmission altogether in the U.S. catfish industry.

This section lays out the theoretical model to link farm price and wholesale price in order to understand the nature of price transmission in the presence of market power in the U.S. catfish processing industry. Market demand for wholesale catfish depends on wholesale price, consumers' income, population, as well as the availability of substitutes such as catfish imports, other fish products, and meat. The inverse demand function at wholesale market is:

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

where, P_w is wholesale price of processed catfish, Q_w is wholesale volume of processed catfish, and **Z** is a vector of demand shifters. Catfish processors buy live catfish as an input into their production, and face a market supply of live catfish as:

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

where, P_f is farm price of live catfish, Q_f is sale volume of live catfish, and **W** is a vector of live catfish supply shifters, such as weather, technology, and feed price. We assume that each processor has the same fixed proportion technology, or $Q_{f,i} = \kappa\, Q_{w,\, i}$. Where, $Q_{f,i}$ is live catfish volume bought by firm i, $Q_{w,i}$ is sale volume of processed catfish of firm i, κ is a constant and $\kappa \geq 1$. A firm's profit function is therefore:

(4) $\Pi_i = P_w(Q_w)\, Q_{w,i} - P_f(Q_f)\, Q_{f,i} - C_i(\mathbf{r}, Q_{w,i})$

where, Π_i is firm i 's profit, Q_f is market farm supply volume ($Q_f = \Sigma\, Q_{f,i}$), Q_w is market wholesale volume ($Q_w = \Sigma\, Q_{w,i}$), C_i is processing cost, and **r** is a vector of input prices, such as wage, energy price, transportation price, capital price. Firm i choose to produce a quantity that maximizes its profit. First-order condition in (4) is as following:

(5) $\partial\Pi_i/\partial Q_{w,i} = P_w + (\partial P_w/\partial Q_w)\, (\partial Q_w/\partial Q_{w,i})\, Q_{w,i} - \kappa\, P_f - (\partial P_f/\partial Q_{f,})\, (\partial Q_f/\partial Q_{w,i})\, Q_{f,i}$

$- \partial C_i(\mathbf{r}, Q_{w,i})/\partial Q_{w,i} = 0$

or,

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

where, $\eta = (\partial Q_w/\partial P_w)(P_w/Q_w)$ is market demand elasticity for wholesale processed catfish, $\varepsilon = (\partial Q_f/\partial P_f)(P_f/Q_f)$ is market supply elasticity of live catfish, and $\theta_i = (\partial Q_w/\partial Q_{w,i})(Q_{w,i}/Q_w)$ is conjectural variation elasticity of firm i. MC_i is marginal cost of firm i, and assuming that firms have the same marginal cost ($MC_i = MC$). Multiplying (5) by processor's market share ($Q_{w,i}/Q_w$), and summing over the number of processors, gains:

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

where, $\Theta = \Sigma(Q_{w,i}\,\theta_i)/Q_w$ is industry conjectural variation elasticity, ranging from 0 to 1. If $\Theta = 0$ processors are price takers in both input and product markets. If $\Theta = 1$, the processing industry acts as a monopoly and/or a monopsony. If Θ ranges between 0 and 1, oligopoly market power = $-\Theta/\eta$, and oligopsony market power = Θ/ε. Dividing both sides of the (6) by $(1 + \Theta/\eta)$, we obtain:

(7) $$P_w = \{\kappa(1 + \Theta/\varepsilon)/(1 + \Theta/\eta)\} P_f + MC/(1 + \Theta/\eta)$$

Equation (7) is a price mark-up equation. Marginal effect of farm price on wholesale price is:

(8) $$\partial P_w/\partial P_f = \kappa(1 + \Theta/\varepsilon)/(1 + \Theta/\eta)$$

The elasticity of price transmission (EPT) is computed by multiplying (8) by P_f/P_w

(9) $$EPT = (\partial P_w/\partial P_f)(P_f/P_w) = \kappa(1 + \Theta/\varepsilon)/(1 + \Theta/\eta)(P_f/P_w)$$

Replacing (7) $P_w = \{\kappa(1 + \Theta/\varepsilon)/(1 + \Theta/\eta)\} P_f + MC/(1 + \Theta/\eta)$ into (9), to get:

(10) $\mathrm{EPT} = \kappa\,(1 + \Theta/\varepsilon)\,P_f \,/\, (\kappa\,(1 + \Theta/\varepsilon)\,P_f + MC)$

The magnitude of elasticity of price transmission (EPT) depends on farm price, marginal cost, farm supply elasticity, and market power. From the formula in (10) we infer that EPT is between 0 and 1 ($0 < \mathrm{EPT} < 1$), since all the elements in (10) are positive.

3.1 Asymmetric Price Transmission (APT)

Asymmetric price transmission refers to the phenomenon that the magnitude of price transmission from farm price to wholesale price is different when farm price increases and decreases. The effect of farm price on the elasticity of price transmission is examined by taking derivative of (10) with respect to farm price (P_f):

(11) $\partial\mathrm{EPT}/\partial P_f = \{\kappa\,(1 + \Theta/\varepsilon)\,MC\}/\{\kappa\,(1 + \Theta/\varepsilon)\,P_f + MC\}^2 > 0$

Partial derivative of elasticity of price transmission (EPT) with respect to farm price (P_f) is positive, meaning that when P_f increases, EPT will increase, or when P_f decreases, EPT will decrease. In other words, holding all else constant, when farm price increases, EPT will be greater than when farm price decreases. Therefore, the transmission of farm price to wholesale price is asymmetric.

3.2 Market Power and Price Transmission

The question is how market power affects the elasticity of price transmission and its asymmetric level. Taking the derivative of (10) in respect Θ to yield:

(12) $\partial\mathrm{EPT}/\partial\Theta = (\kappa\,P_f\,MC/\varepsilon)/\{\kappa\,(1 + \Theta/\varepsilon)\,P_f + MC\}^2 > 0$

The result shows that market power has a positive effect on price transmission. If processors hold market power, price will be more effectively transmitted from farm gate to wholesale market. The effect of market power on the symmetry of price transmission is investigated by taking derivatives of (11) with respect to market power index (Θ):

$$(13) \qquad \partial(\partial EPT/\partial P_f)/\partial\Theta = \{\kappa\, MC\, [MC - \kappa\, (1 + \Theta/\varepsilon)\, P_f]/\varepsilon\}/\{\kappa\, (1 + \Theta/\varepsilon)\, P_f + MC\}^3$$

The sign of (13) is uncertain. If $MC - \kappa\, (1 + \Theta/\varepsilon)\, P_f > 0$, market power increases the level of asymmetry in price transmission; and if $MC - \kappa\, (1 + \Theta/\varepsilon)\, P_f < 0$, market power decreases the level of asymmetry in price transmission. And if $MC - \kappa\, (1 + \Theta/\varepsilon)\, P_f = 0$, market power does not have an effect on the level of asymmetry in price transmission.

Market power helps catfish processors to extract more profit from catfish growers and retailers. Therefore, catfish processors' market power will cause reductions in production volume at farm and wholesale market. Farm price will decrease while wholesale price will increase. This means that wholesale-farm margin will be higher. In other words, processors will gain, while producers, retailers, and consumers will lose. The effect of asymmetry in price transmission on welfare is theoretically and empirically unknown.

4. Empirical Estimations and Results

4.1 Testing for APT

The common equation employed to test price transmission is specified as:

$$(14) \qquad P_t^{out} = a_0 + a_1 {*} P_t^{in} + a_2 {*} Z_t + \varepsilon_t$$

where, P_t^{out} is output price or downstream price, P_t^{in} is input price or upstream price, Z is a vector of exogenous variables. The econometric estimation of (14) provides information on price transmission from P^{in} to P^{out}. The parameter a_1 is expected to be significantly different from zero, and positive. If we use a log-linear specification in estimation of (14), a_1 will be the elasticity of price transmission (EPT), and $0 < EPT < 1$. Asymmetric price transmission refers to the phenomenon that price transmissions defer accordingly to the increase or the decrease in prices (Meyer and Von Cramon-Taubadel, 2004); and Peltzman (2000) found that most prices rise faster than they fall. Houck (1977) proposed a simple method to test for asymmetry in price transmission. The test model is:

$$(15) \qquad \Delta P_t^{out} = \alpha_0 + \sum_{i=0}^{n} \beta_i D^{+} \Delta P^{in}_{t-i} + \sum_{i=0}^{n} \theta_i D^{-} \Delta P^{in}_{t-i} + \varepsilon_t$$

where, Δ is first difference operator; $i = 0,1,2\ldots n$; and D^+ and D^- are dummy variables. $D^+ = 1$ when $\Delta P^{in}_t > 0$, otherwise $D^+ = 0$. $D^- = 1$ when $\Delta P^{in}_t < 0$, otherwise $D^- = 0$. The dummy variables D^+ and D^- separate the effects of increasing and decreasing farm price on wholesale price. The test of asymmetry in price transmission is equal to a test of the null hypothesis:

$$H_0: \sum_{i=0}^{n} \beta_i = \sum_{i=0}^{n} \theta_i$$

vs.

$$H_1: \sum_{i=0}^{n} \beta_i \neq \sum_{i=0}^{n} \theta_i$$

This is a linear combination hypothesis test, using the Wald test. The price transmission is asymmetric if the Wald test rejects the null hypothesis. Ordinary least squares (OLS) method is used to estimate (15) and to conduct a test of the null hypothesis. The price transmission model (15) is estimated for different data sets on wholesale price (P_t^{out}) such as, aggregate price, whole fish price, and fillet price. Price paid to catfish producers at the farm level will be used as the upstream price (P_t^{in}). The data are monthly, from January 1988 to December 2008, and collected from the United States Department of Agriculture (USDA). Estimated results are presented in Table 1. The estimated models have significant coefficients with two lags. The estimations of price transmission equations show no problem of autocorrelation, heteroscedasticity, and normality. The Wald test rejects the null hypothesis in aggregated and whole fish models, meaning that farm prices are transmitted asymmetrically to aggregated and whole fish prices. The Wald test fails to reject the null hypothesis for the fillet model, implying that farm price is transmitted symmetrically to fillet price. Farm price is transmitted to whole fish price more completely than to fillet price. The results seem rational since fillet requires more time and labor to produce than whole fish. When farm price increases, short-run and long-run elasticities of price transmission are 0.4 and 0.6 in the aggregate model, 0.43 and 0.70 in the whole fish model, and 0.23 and 0.45 in the fillet model. When farm price decreases, short-run and long-run elasticities of price transmission are 0.21 and 0.34 in the aggregate model; 0.28 and 0.32 in the whole fish model; and 0.19 and 0.35 in the fillet model.

4.2 Co-integration Testing for APT

Granger and Newbold (1974) proved that OLS method with non-stationary time series variables will produce spurious results. The spurious models often have autocorrelation problems that may lead to incorrect hypothesis testing. Since most price series are non-stationary, Von Cramon-Taubadel and Fahlbusch (1994), Von Cramon-Taubadel (1998), and Von Cramon-Taubadel and Loy (1999) have developed methods to deal with spurious problems based on the cointegration concept and methods proposed by Engle and Granger (1987), Johansen (1988). The empirical model to test for APT developed by Von Cramon-Taubadel and Fahlbusch (1994) is:

$$(16)\qquad \Delta P^{out}_{t} = \alpha_0 + \sum_{i=0}^{n} \beta_i \, \Delta P^{out}_{t-1-i} + \sum_{i=0}^{n} \theta_i \, \Delta P^{in}_{t-i} + \gamma \, ECT_{t-1} + \varepsilon_t$$

where, ECT is the error correction term, obtained from predicted residuals in OLS estimation of (14). The asymmetry of price transmission can be tested when separating ECT and ΔP^{in} into positive and negative components. And Von Cramon-Taubadel and Loy (1999) elaborated the model (16) by separating exogenous price components and error correction terms:

$$(17)\qquad \Delta P_t^{out} = \alpha_0 + \sum_{i=0}^{n} \beta_i \, \Delta P^{out}_{t-1-i} + \sum_{i=0}^{n} \theta^{+}_{i} \, D^{+}\Delta P^{in}_{t-i} + \sum_{i=0}^{n} \theta^{-}_{i} \, D^{-}\Delta P^{in}_{t-i} + \gamma^{+} \, ECT^{+}_{t-1} + \gamma^{-} \, ECT^{-}_{t-1} + \varepsilon_t$$

where, $ECT^{+}_{t} = ECT_t$ when $ECT_t > 0$, otherwise $ECT^{+}_{t} = 0$; $ECT^{-}_{t} = ECT_t$ when $ECT_t < 0$, otherwise $ECT^{-}_{t} = 0$. The error correction mechanism means that a proportion of disequilibrium from a period is corrected in the next period. Therefore, the ECM models allow us to estimate short-run adjustments in the presence of long-run dynamic adjustment toward the equilibrium of variables. The ECM model allows us to test for asymmetry in price transmission in both the short-run and long-run perspectives. The short-run price transmissions are captured through the coefficients of farm price, θ^{+}_{i} andθ^{-}_{i}. The long-run price transmissions are captured through the coefficients of ECT terms, γ^{+} and γ^{-}. The test for asymmetry of price transmission is equal to testing the hypothesis:

$$H_0: \sum_{i=0}^{n} \theta^{+}_{i} = \sum_{i=0}^{n} \theta^{-}_{i} \text{ and } \gamma^{+} = \gamma^{-}$$

vs.

$$H_1: \sum_{i=0}^{n} \theta^{+}_{i} \neq \sum_{i=0}^{n} \theta^{-}_{i} \text{ and/or } \gamma^{+} \neq \gamma^{-}$$

Joint “F-test” of linear combinations will be employed to test the null hypothesis. If the test fails to reject the null hypothesis, price transmission in the U.S. catfish industry is symmetric. If the alternative hypothesis (H_1) is accepted, price transmission is asymmetric.

The test of asymmetric price transmission using the cointegration approach goes through the following steps: (i) test for unit root among price series; (ii) test for existence of cointegrating vector among unit root price series, and to obtain error correction terms; (iii) construct dummy variables for positive and negative price differences, and error correction terms, and to estimate the error correction model as in (17). The test for unit root is presented in Table 2, both Augmented Dickey-Fuller and Phillips-Perron tests show that farm and wholesale prices are non-stationary, and have unit roots. Long-run equilibrium relationship between price series is tested and estimated. The results of cointegration test and cointegrating vector are presented in Table 3. The cointegration rank tests show that there is a unique long-run equilibrium relationship between variables in all three models, aggregate, whole fish, and fillet. Engel-Granger causality test concludes that farm price has a causal effect on wholesale price, but not the opposite. Meyer and Von Cramon-Taubadel (2004) pointed out that cointegration and ECM are developed from the idea of a long-run equilibrium, which prevents the price series from drifting apart. Therefore, in the long-run, there is no APT because if there is a permanent difference between positive and negative transmission, price series will go apart and cannot be cointegrated. In other words, long-run price transmission is symmetric by presumption in the cointegration approach. The long-run elasticities of price transmission are 0.73 for the aggregate model, 0.72 in the whole fish model, and 0.70 in the fillet model.

In the cointegration approach, the asymmetry of price transmission is only relevant in short-run and perhaps in respect to the speed of price transmission. The estimation results of (17) are presented in Table 4. The estimated models have no problem of autocorrelation, heteroscedasticity, and normality. Farm prices significantly affect wholesale prices up to two lags for all models. The Wald test rejects the null hypothesis of symmetric price transmission. The increase in farm price has larger effects on wholesale price than the decrease in farm price. Short-run asymmetry in price transmission appears obvious in all three models. When farm price increases, the short-run elasticities of price transmission are 0.45 for the aggregate model, 0.47 for the whole fish model, and 0.28 for the fillet model. When farm price decreases, the short-run elasticities of price transmission are 0.27 in the aggregate model, 0.30 in the whole fish model, and 0.21 in the fillet model. Obviously, positive price transmission has higher speed than that of negative price transmission. In the aggregate model, about 62% of full positive price transmission is realized spontaneously, and only 40% of full negative price transmission is realized spontaneously. Similar figures are 65% and 42% for the whole fish model, and 40% and 30% for the fillet model. Error correction terms (ECT) have expected negative signs. Wald test failed to reject the null hypothesis, meaning that long-run price transmission is symmetric. The estimated coefficient of ECT^+ is statistically significant, while the estimated coefficient of ECT^- is statistically insignificant. Positive error correction term (ECT^+) implies that farm price decreases or wholesale price increases. Since we are concerned about the direction of transmission from farm price to wholesale price, ECT^+ is assigned to decreasing farm price. The estimated coefficient of ECT^+ is negative, - 0.073. In brief, a decreasing farm price is well transmitted to a decreasing wholesale price through the error correction terms (ECT) over the long-run. The results imply that long-run error correction term will correct the asymmetric transmission of price in the short-run.

4.3 Testing for Market Power

The test of market power involves estimation of a system of equations (1), (2), and (7) and then test for the significance of estimated Θ. Empirical specification of the market demand function for wholesale processed catfish (1) is:

(18) $\log(\text{Processorvolume}) = a_0 + a_1*\log(\text{Processorprice}/\text{CPI}) + a_2*\log(\text{GDP}/\text{CPI}) + a_3*\log(\text{POP}) + a_4*\log(\text{Meatprice}/\text{CPI}) + a_5*\log(\text{Import}) + f_1*D_1 + f_2*D_2 + f_3*D_3 + f_4*D_4 + f_5*D_5 + f_6*D_6 + f_7*D_7 + f_8*D_8 + f_9*D_9 + f_{10}*D_{10} + f_{11}*D_{11}$

where, Processorvolume is wholesale volume of processed catfish, Processorprice is wholesale price of processed catfish, GDP is the U.S. gross domestic production in nominal money terms, Meatprice is meat price index, POP is the U.S. population, Import is catfish import volume. Variables D_1 to D_{11} are dummies for months January to November, accounting for seasonal data effects. The expected sign of a_1 is negative; the expected signs of a_2 and a_3 are positive; the expected sign of a_5 is negative since imports compete with domestic production; the expected sign of a_4 is positive if meat is a substitute for catfish, and negative if meat is a complement for catfish.

General farm supply function (2) of live catfish is empirically specified under the assumption that catfish growers adjust production based on profit levels. The normalized profit function approach is employed to specify the catfish farm supply function. Fixed factors in catfish farm production are included in the farm supply function using farm size for the long-term production adjustment. The time variable is used to measure technological effects. The empirical model of farm supply is:

(19) $\log(\text{Farmvolume}) = \log(1-b_1-b_2-b_3) + b_1*\log(\text{Feedprice}/\text{Farmprice}) + b_2*\log(\text{Energyprice}/\text{Farmprice}) + b_3*\log(\text{Interest}/\text{Farmprice}) + b_4*\log(\text{Farmsize}) + b_5*\text{Year} + g_1*D_1 + g_2*D_2 + g_3*D_3 + g_4*D_4 + g_5*D_5 + g_6*D_6 + g_7*D_7 + g_8*D_8 + g_9*D_9 + g_{10}*D_{10} + g_{11}*D_{11}$

where, Farmvolume is volume of live catfish sold to processors, Farmprice is price of live catfish paid to farmers, Feedprice is price of catfish feed, Energyprice is price index of energy in the U.S., Interest is bank prime interest rate used as price of capital, Farmsize is average acre per catfish farm. Expected signs of b_1-b_3 are negative. Expected signs of b_4 and b_5 are positive. Supply elasticity is equal to: $-(b_1+b_2+b_3)$.

The relationship between farm price of live catfish and wholesale price of processed catfish is described in Equation (7). Parameter κ is a constant, and the value of κ is identified for a specific industry. The value of κ is about 2 in the U.S. catfish industry (Figure 5). In this study, κ is assumed to be one as in most previous studies for a convenience in empirical estimation. Letting the conjectural variation elasticity oscillate with the number of processing firms, $\Theta = e_0 + e_1*\text{Firm}$, where, Firm is number of catfish processors. The empirical specification of (7) is presented below:

(20) $\text{Processorprice} = \text{Farmprice}*\{1 + (e_0 + e_1*\text{Firm})/(-b_1-b_2-b_3)\}/\{1 + (e_0 + e_1*\text{Firm})/a_1\} + \{c_1*\text{Wage} + c_2*\text{Energyprice} + c_3*\text{Transportprice} + c_4*\text{Interest} + 2*c_5*(\text{Wage}*\text{Energyprice})^{0.5} + 2*c_6*(\text{Wage}*\text{Transportprice})^{0.5} + 2*c_7*(\text{Wage}*\text{Interest})^{0.5} + 2*c_8*(\text{Energyprice}*\text{Transportprice})^{0.5} + 2*c_9*(\text{Energyprice}*\text{Interest})^{0.5} + 2*c_{10}*(\text{Transportprice}*\text{Interest})^{0.5}\}/(1 + (e_0 + e_1*\text{Firm})/a_1)$

where, Wage is wage index of goods producing sector, Transportprice is price index of transportation. The expected sign of e_0 is positive and e_1's is negative. The expected signs of c_1-c_4 are positive, and c_5-c_{10}'s can be positive or negative depending on whether the corresponding inputs are substitutes or complements.

Data are monthly, available from January 1988 to December 2008. Data on catfish are collected from USDA's various reports. Catfish feed prices are extracted from Hanson and Sites (2009). Data on price indices are from The Bureau of Labor Statistics. Other data are from The Bureau of Economic Analysis (BEA), and U.S. Census. The system of equations (18), (19), and (20) is estimated using nonlinear three-stage least squares method (3SLS). The estimation results are presented in Table 5. The results show anticipated negative signs of price on demand, with wholesale catfish demand elasticity of -0.54. Income has significant positive effect on demand of catfish as expected. A 1% increase in income causes 0.51% increase in catfish demand, implying that catfish is a normal good. Catfish import has a negative effect on catfish demand. Meat and catfish are not substitutes. Surprisingly, catfish seems to be a complement to meat since the estimated coefficient of a_4 is negative. When meat price increases, consumers will eat less meat and less catfish also, and vice versa. Catfish imports compete with domestic catfish products. A 1% increase in catfish import causes a 0.05% decrease in demand for domestic catfish. Live catfish supply elasticity is 0.119. Price of inputs, such as feed, energy, and capital all negatively affect farm supply. Farm size and technological improvement both have positive effects on live catfish supply as expected. Dummy variables for seasonality are all significant, and account for the seasonal pattern of live catfish and processed catfish volumes.

The estimation of (20) shows that catfish farm price significantly and positively affect wholesale price of processed catfish. Marginal effect of farm price on wholesale price, $\partial\text{Processorprice}/\partial\text{Farmprice} = \{1 + (e_0 + e_1{*}\text{Firm})/(-b_1-b_2-b_3)\}/\{1 + (e_0 + e_1{*}\text{Firm})/a_1\} = 1.523$, and average elasticity of price transmission, EPT =

1.523*(Farmprice/Processorprice) = 0.48. Input prices relate positively to wholesale prices which means a increase/decrease in input price increase/decrease will lead to wholesale price increase/decrease, except for energy price. The results show that labor and energy are complementary production inputs, meaning that in catfish processing, labor and energy move together. Similarly, labor and transportation are complements. In contrast, labor and capital are substitutes in catfish processing, if processors use more capital, they will employ less labor. Energy and capital are complements.

The industry conjectural variation elasticity is, $\Theta = e_0 + e_1$*Firm = 0.06. The sign of e_0 is positive as expected, and the sign of e_1 is negative as expected. The number of catfish processors has a negative effect on the industry conjectural variation elasticity. In other words, the number of processors has a negative effect on the catfish industry conjectural variation elasticity, and so on its market power. The computed average oligopoly power index is $- \Theta/\eta = - (e_0 + e_1$*Firm$)/a_1 = 0.111$, and the computed average oligopsony power index is $\Theta/\varepsilon = (e_0 + e_1$*Firm$)/(-b_1-b_2-b_3) = 0.50$. In the last two decades, the data show that the number of processors is decreasing (Figure 4b). Therefore, the catfish industry conjectural variation elasticity is increasing in the last 20 years (Figure 6). As a result, the U.S. catfish industry market power is increasing during the study period.

5. Welfare Distribution

Oligopsony market power is the ability of processors to set the price paid to catfish growers lower by reducing live catfish quantity bought from growers. Oligopsony reduces the economic surplus of catfish growers. Figure 8 shows the graph of farm market with the processor exerting oligopsony power. The loss in producer surplus is the areas of A + B + C, and equal to:

(21) $\Delta PS = \frac{1}{2} (P_0 - P)*(Q + Q_0)$

where, ΔPS is change in producer surplus. P and Q are farm price and farm volume, and observed in the market. P_0 and Q_0 are farm price and farm volume in the case of perfect competition. The "perfect competitive" farm price (P_0) is computed as, $P_0 = (1 + \Theta/\varepsilon) P$. Since farm supply elasticity $\varepsilon = (\Delta Q/\Delta P)*(P/Q) = \{(Q_0 - Q)/(P_0 - P)\}*(P/Q)$, then the "perfect competitive" farm volume is computed as, $Q_0 = \varepsilon*Q*(P_0 - P)/P + Q = Q(1 + \Theta)$. To replace P_0 and Q_0 in to (21), get:

(22) $\Delta PS = \frac{1}{2} P*Q*(\Theta/\varepsilon)*(2 + \Theta)$

The loss in producer surplus is caused by the oligopsony market power, and higher conjectural variation cause higher loss in producer surplus. Farm supply elasticity negatively relates to loss in producer surplus. In other words, if growers have higher ability to alter their production quantity to price change, they will suffer less economic losses due to oligopsony power exerted by processors. Oligopsony market power brings economic gain to processors. The gain to processors is equal to the areas of A + B - D (Figure 8):

(23) $\Delta CS = \frac{1}{2} (P_0 - P)*Q - \frac{1}{2} (P' - P_0)*(Q_0 - Q)$

We assume that η_a is the demand elasticity for live catfish at the farm market. Hence, $\eta_a = \{(Q_0 - Q)/(P_0 - P')\}*(P_0/Q_0)$. Therefore, $P' - P_0 = \{(Q - Q_0)*P_0\}/(Q_0*\eta_a)$. To replace $(P' - P_0)$, P_0, and Q_0 into (23), we obtain:

(24) $\Delta CS = ½\ P*Q*(\Theta/\varepsilon) + ½\ P*Q*\Theta^2*(1 + \Theta/\varepsilon)/\{(1 + \Theta)*\eta_a\}$

The total deadweight loss caused by oligopsony market power in farm market is the sum of areas C + D, see Figure 8, and equal to:

(25) $\Delta TS = \Delta PS - \Delta CS = (A + B + C) - (A + B - D) = C + D.$

Oligopoly power helps processors to increase wholesale price by reducing the volume supplied. Oligopoly market power causes a loss to retailers. The loss of consumer surplus is the areas of A + B + C, see Figure 9, equal to:

(26) $\Delta CS = ½\ (P – P_0)*(Q + Q_0)$

where, ΔCS is change in consumer surplus. P and Q are observable price and quantity of processed catfish at the wholesale market. P_0 and Q_0 are “perfect competitive” price and quantity of processed catfish. Where, “perfect competitive wholesale price” is computed as $P_0 = P\ (1 + \Theta/\eta)$; and “perfect competitive” wholesale volume is, $Q_0 = Q\ (1 + \Theta)$. To replace P_0 and Q_0 into (26), yields:

(27) $\Delta CS = -\ ½\ P*Q*(\Theta/\eta)*(2 + \Theta)$

Higher oligopoly power among processors generates larger losses to catfish consumers. Higher market demand elasticity in the wholesale market reduces consumer losses caused by market power exerted by processors. Oligopoly power also generates economic surplus to processors. The gain to processors is equal to the areas of A + B – D (Figure 9):

(28) $\Delta PS = \frac{1}{2} (P - P_0)*Q - \frac{1}{2} (P_0 - P')*(Q_0 - Q)$

We assume that ε_a is the supply elasticity for processed catfish at the wholesale market. Hence, $\varepsilon_a = \{(Q_0 - Q)/(P_0 - P')\}*(P_0/Q_0)$. Therefore, $P_0 - P' = \{(Q_0 - Q)*P_0\}/(Q_0*\varepsilon_a)$. To replace $(P_0 - P')$, P_0, and Q_0 into (28), we get:

(29) $\Delta PS = \frac{1}{2} P*Q*(-\Theta/\eta) + \frac{1}{2} P*Q*\Theta^2*(1 + \Theta/\eta)/\{(1 + \Theta)*\varepsilon_a\}$

Total deadweight loss in the wholesale market is the sum of areas C + D, see Figure 9, and equal to:

(30) $\Delta TS = \Delta CS - \Delta PS = (A + B + C) - (A + B - D) = C + D.$

Empirical estimation of economic surplus among producers and consumers in both farm and wholesale market are presented in Table 6. For comparison, the estimation of economic surplus is conducted using two scenarios, low and high levels of responsiveness in wholesale demand and farm supply. The first case with wholesale demand elasticity of $\eta = - 0.54$, and farm supply elasticity of $\varepsilon = 0.119$, which are obtained from empirical estimation of the system of (18), (19), and (20). The second case uses higher value of $\eta = - 2$, and $\varepsilon = 0.8$ in the estimation of economic surplus to demonstrate the ideas that larger responsiveness in wholesale demand and farm supply will lessen the economic losses to producers and consumers brought about by the market power exerted by processors. In both cases, for convenience in computations, we assume that supply elasticity at wholesale market $\varepsilon_a = 1$, and demand elasticity at farm market $\eta_a = -1$.

The results in Table 6 show that processors' oligopsony power forces price paid to catfish growers downward between \$0.05 and \$0.37 per pound depending on the magnitude of farm supply elasticity. Processors' oligopsony power causes a decrease in live catfish production of about 2.6 million pounds a month, and cost producers a loss of about \$2.3 million to \$15.8 million per month. Oligopsony power brought extra profit to processors of about \$1 million to \$7.6 million a month. The deadweight loss to society from oligopsony power is large, and ranges from \$1.3 million to \$8.2 million a month.

Oligopoly market power helps catfish processors to charge a wholesale price higher than the competitive price which ranged from \$0.069 to \$0.254 per pound, and reduces the quantity supplied of 1.285 million pounds per month. The Oligopoly power brought a profit of \$0.81 million to \$2.76 million to processors, on average, each month. However, Oligopoly power costs consumers an extra amount of \$1.5 million to \$5.5 million each month. The deadweight loss to society due to oligopoly power is from \$0.69 million to \$2.77 million a month.

6. Summary and Conclusion

A theoretical model is developed to link the catfish farm market with the wholesale market. The model predicts that elasticity of price transmission is asymmetric, ranging between 0 and 1, and market power positively affects elasticity of price transmission, but has indecisive effects in asymmetric level of price transmission.

Empirical tests, using Houck's method, generate short-run elasticity of price transmission of 0.4 and long-run of 0.6. Co-integration method gives short-run price transmission elasticity of 0.45 and long-run of 0.73. Price transmission is asymmetric, about 62% of positive price transmission and 40% of negative price transmission are realized spontaneously. The error correction term is included in the test of price transmission. The results show that asymmetry in price transmission is a short-run matter. Over the long-run, error correction term will correct the asymmetric transmission of price. Elasticities of price transmission are different across product forms. Wholefish product has larger elasticity of price transmission, and fillet has the smallest.

Test for market power, using three-stage least squares method, found a significant industry conjectural variation elasticity of 0.06. The number of catfish processors has a negative effect on the industry conjectural variation elasticity. The average oligopoly power index is 0.111, and the average oligopsony power index is 0.50. Average computed elasticity of price transmission is 0.48. Empirical evidence shows that market power negatively affects elasticity of price transmission and farm price has a positive effect on elasticity of price transmission. The results confirm asymmetry in price transmission, and market power is not a decisive factor to the asymmetry of price transmission.

Processros' oligopsony power forces price paid to catfish growers downward from \$0.05 to \$0.37 per pound and causes a decrease in live catfish production of 2.6 million pounds a month. Oligopsony power brought extra profit to processors of about \$1 million to \$7.6 million, but costs producers a loss of \$2.3 million to \$15.8 million per month. Deadweight loss to society of oligopsony power is from \$1.3 million to \$8.2

million a month. Oligopoly market power helps catfish processors to be able to charge a wholesale price higher than the competitive price of $0.069 to $0.254 per pound, and reduce their quantity supplied of 1.285 million pounds per month. The oligopoly power brought a profit of $0.81 million to $2.76 million to processors, on average, each month. However, oligopoly power costs consumers an amount of $1.5 million to $5.5 million each month. The deadweight loss to society of oligopoly power is from $0.69 million to $2.77 million a month.

Appendix 2

Table 1: **Houck's Test Model Estimation**

Parameters	Aggregate model		Whole fish model		Fillet model	
	Estimate	t-value	Estimate	t-value	Estimate	t-value
Intercept	-0.00414	-1.48	-0.00564	-2.02	-0.00162	-0.67
$D^{+}\Delta P^{in}_{t-1}$	0.012674**	7.69	0.009984**	6.06	0.008926**	6.26
$D^{+}\Delta P^{in}_{t-2}$	0.006376**	3.89	0.006181**	3.77	0.008471**	5.98
$D^{-}\Delta P^{in}_{t-1}$	0.00659**	3.40	0.006482**	3.34	0.007202**	4.29
$D^{-}\Delta P^{in}_{t-2}$	0.004213*	2.16	0.001005	0.52	0.006071**	3.61
R^2						
DW	2.53		2.33		2.27	
White test	79.75 (0.0001)		47.40 (0.0001)		18.56 (0.0997)	
Shapiro-Wilk test (p)	0.8365		0.9734		0.0623	
Wald test	6.71 (0.0096)		7.45 (0.0064)		2.25 (0.13390	

Note: * is significant at 10%;** is significant at 5%;*** is significant at 1%;

Table 2: **Unit Root Test**

Variables	ADF test				PP test		Conclusion
	τ	Pr < τ	**Φ**	Pr > Φ	τ	Pr < τ	
Farm price	-3.47	0.0454	6.06	0.0628	-2.39	0.3856	I(1)
Wholesale price	-2.98	0.1409	4.44	0.2863	-2.51	0.3209	I(1)
Whole fish price	-3.09	0.1114	4.77	0.2192	-2.75	0.2168	I(1)
Fillet price	-2.47	0.3428	3.25	0.5254	-1.76	0.7243	I(1)

Notes: number of observation = 252; 95% critical of τ = - 3.43; (iii) 95% critical value of Φ = 4.75.

Table 3: Cointegration Rank Test

	Variables	Causality test		Cointegration rank test				Cointegration vector
		Chi-Square	Pr > ChiSq	H0: rank = r	H1: rank > r	Trace	5% critical value	
Aggregate model	Wholesale	7.2	0.0073	0	0	20.242	19.99	1
	Farm price	0.1	0.7464	1	1	3.5004	9.13	-0.0232
	Constant							-0.6092
	Elasticity of Price transmission = 0.73							
Wholefish model	Wholesale	22.50	<.0001	0	0	34.547	19.99	1
	Farm price	1.86	0.1732	1	1	4.3580	9.13	-0.0167
	Constant							-0.4567
	Elasticity of Price transmission = 0.72							
Fillet model	Wholesale	14.70	0.0001	0	0	30.087	19.99	1
	Farm price	0.27	0.6058	1	1	3.5849	9.13	-0.0266
	Constant							-0.8300
	Elasticity of Price transmission = 0.69							

Table 4: **Error Correction Model with Asymmetric Price Transmission**

Variables	Aggregate model		Whole fish model		Fillet model	
	Estimate	t-value	Estimate	t-value	Estimate	t-value
lag(Δwholesaleprice)	-0.27277	-4.92**	-0.13107	-2.16*	-0.13049	-2.11*
lag(ECT^+)	-0.07281	-2.22*	-0.14751	-2.54**	-0.1095	-2.56**
lag(ECT^-)	-0.04305	-1.63	-0.09232	-1.58	-0.00722	-0.19
constant	-0.00509	-1.62	-0.00512	-1.42	-0.00045	-0.13
D^+ Δfarmprice	0.014132	13.26**	0.01093	6.8**	0.01050	7.26**
lag(D^+ Δfarmprice)	0.008233	5.26**	0.005452	2.95**	0.00752	4.55**
lag2(D^+ Δfarmprice)	0.002724	1.79	0.00217	1.33	0.003325	2.23*
D^- Δfarmprice	0.008518	5.01**	0.006954	3.73**	0.007896	4.7**
lag(D^- Δfarmprice)	0.003519	2.06*	-0.00099	-0.48	0.004587	2.49*
lag2(D^- Δfarmprice)	0.002853	1.29	0.002865	1.5	0.001621	0.92
R^2	0.4932		0.3977		0.5261	
DW	2.0555		2.023		1.9867	
Shapiro-Wilk test (P-value)	0.5756		0.9777		0.2847	
Wald test: b1+b2+b3-b4-b5-b6=0	8.69 (0.0032)		7.21 (0.0073)		4.90 (0.0269)	
Wald test: c1-c2=0	0.45 (0.5016)		0.31 (0.5762)		2.23 (0.1358)	

Note: * is significant at 10%;** is significant at 5%;*** is significant at 1%;

Table 5: **3SLS Estimation of Market Linkage and Market Power**

Parameters	Estimate	Std Error	t value
a0	1.722	2.0239	0.85
a1	-0.542***	0.0854	-6.35
a2	0.510**	0.2573	1.98
a3	0.677	0.7375	0.92
a4	-0.719***	0.1466	-4.91
a5	-0.056***	0.00615	-9.06
b1	-0.025	0.0459	-0.55
b2	-0.028	0.0387	-0.73
b3	-0.119***	0.0306	-3.89
b4	0.405***	0.0245	16.54
b5	0.004***	0.000076	53.45
c1	115.959***	23.4079	4.95
c2	-5.637**	2.2407	-2.52
c3	81.132***	19.6749	4.12
c4	15.054*	8.0556	1.87
c5	4.661	3.7034	1.26
c6	37.577***	12.0334	3.12
c7	-99.300***	21.5871	-4.60
c8	1.138	4.1866	0.27
c9	2.284	3.0911	0.74
c10	-32.965***	11.8343	-2.79
e0	0.069***	0.0184	3.73
e1	-0.0003	0.000289	-1.04
f1	0.187***	0.0259	7.23
f2	0.227***	0.026	8.74
f3	0.301***	0.0262	11.47
f4	0.157***	0.0259	6.07
f5	0.215***	0.0264	8.17
f6	0.153***	0.0258	5.95
f7	0.182***	0.0256	7.10
f8	0.221***	0.0255	8.65
f9	0.156***	0.0254	6.15
f10	0.202***	0.0253	7.98
f11	0.047*	0.0253	1.86
g1	0.133***	0.0316	4.21
g2	0.139***	0.0316	4.42
g3	0.236***	0.0317	7.45
g4	0.100***	0.0317	3.17
g5	0.094***	0.0322	2.92
g6	0.065**	0.0317	2.04
g7	0.092***	0.0316	2.92
g8	0.145***	0.0316	4.58
g9	0.108***	0.0316	3.42
g10	0.163***	0.0316	5.16
g11	0.057*	0.0316	1.79

Table 6: **Effects of Market Power on Welfare Distribution at Farm and Wholesale Markets**

Parameters	Unit	$\eta = -0.54, \varepsilon = 0.119$		$\eta = -2, \varepsilon = 0.8$	
		Farm Market (Oligopsony)	Wholesale (Oligopoly)	Farm Market (Oligopsony)	Wholesale (Oligopoly)
ΔPrice	Cent	-36.5	+25.4	-5.4	+6.8
ΔVolume	1000 lbs	-2,572.7	-1,285.6	-2,572.7	-1285.6
ΔPS	dollar/month	-15,829,552.8	+2,761,669.9	- 2,354,613.6	+809,818.7
ΔCS	dollar/month	+7,600,973.7	-5,538,580.5	+1,085,892.6	- 1,501,619.0
ΔTS	dollar/month	-8,228,579.0	-2,776,910.5	-1,268,721.0	-691,800.2
Total revenue	dollar/month	29,971,860.1	47,781,944.7	29,971,860.1	47,781,944.7

Note: Assuming $\varepsilon_a = 1$, $\eta_a = -1$

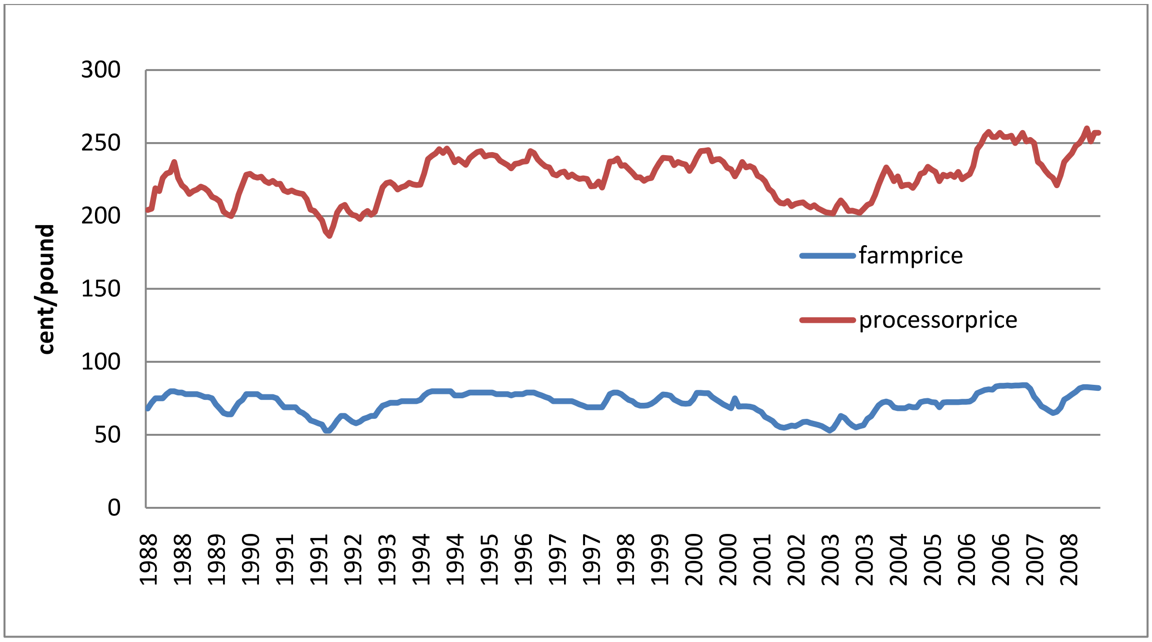

Figure 1: **Farm Price and Wholesale Price (cent/pound)**

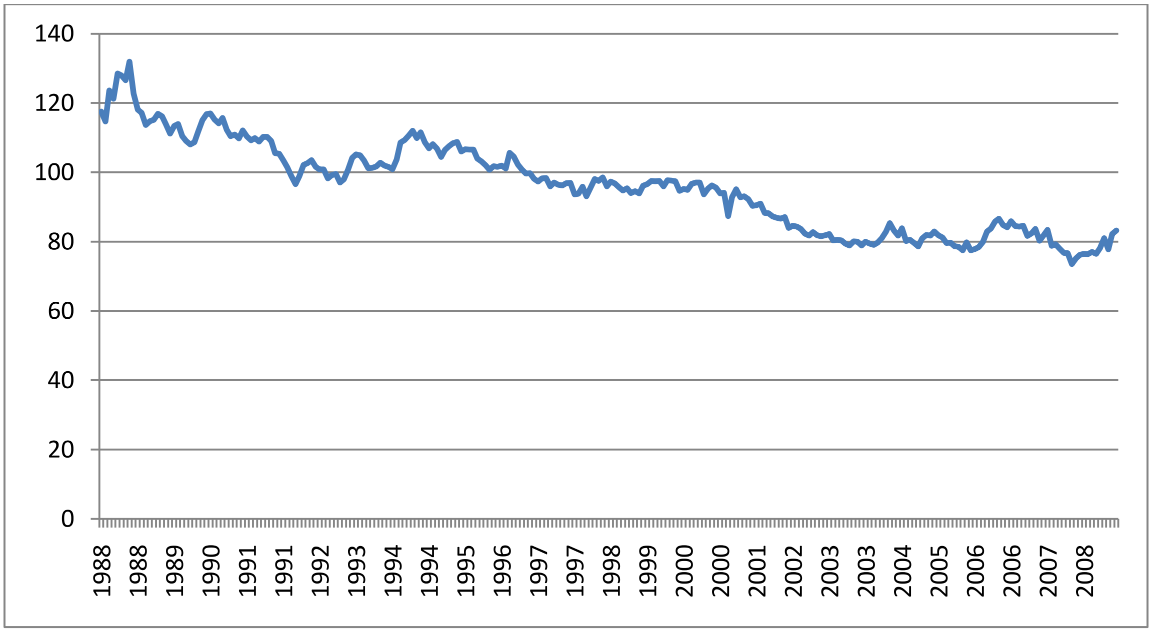

Figure 2: **Real Farm-Wholesale Margin (cent/pount)**

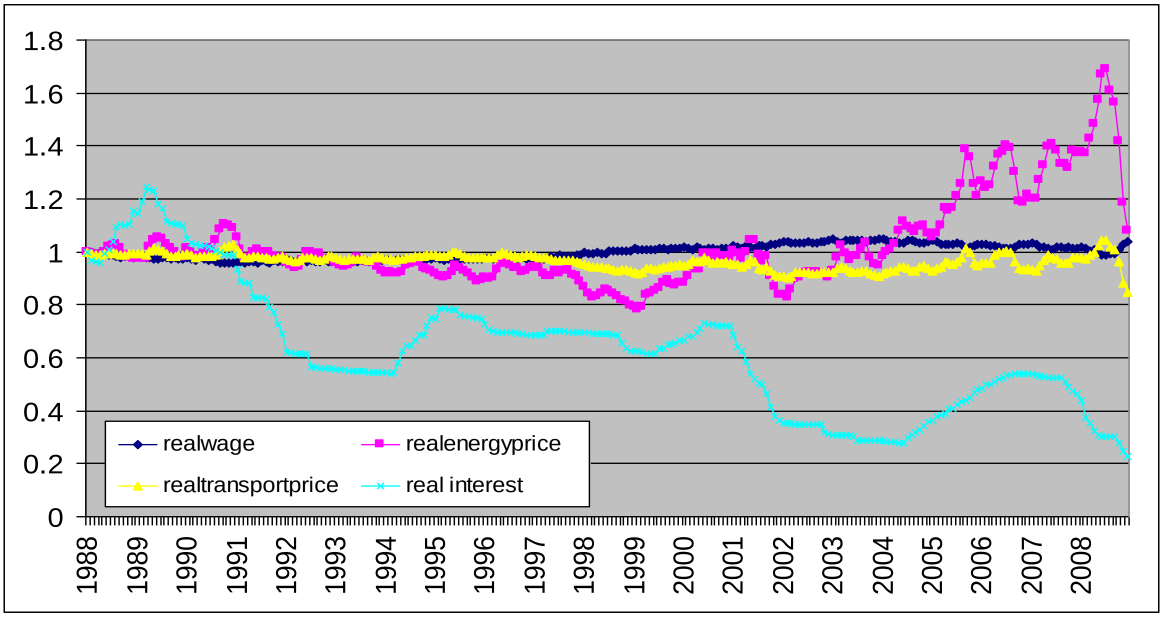

Figure 3: **Real Input Price Indices**

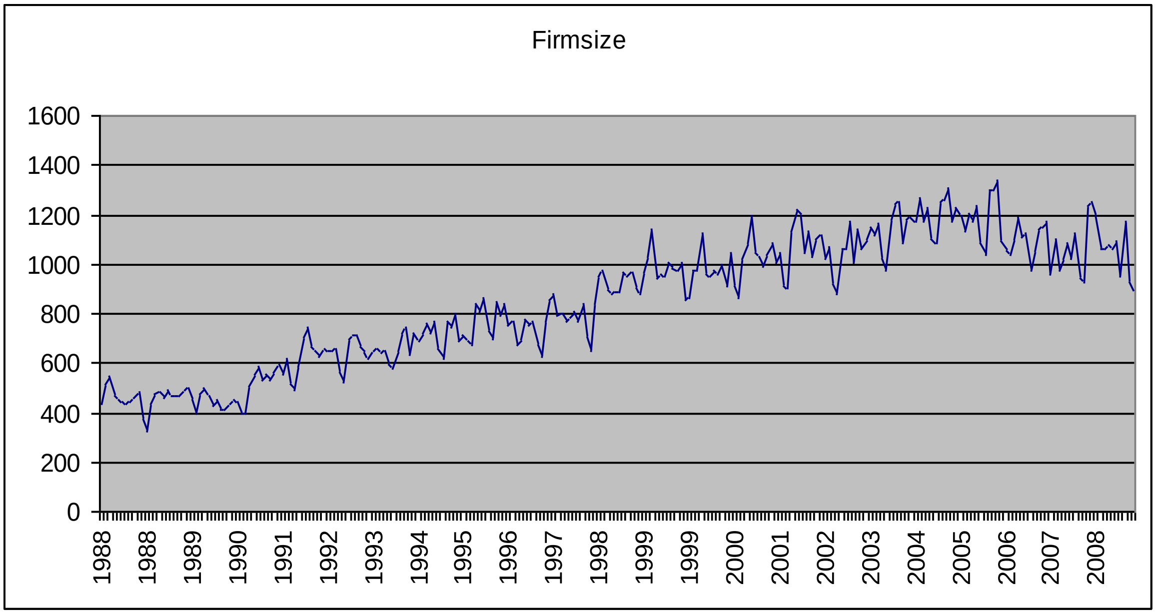

Figure 4a: **Average Catfish Pocessors' Capacity per Month (1000 lbs/plant/month)**

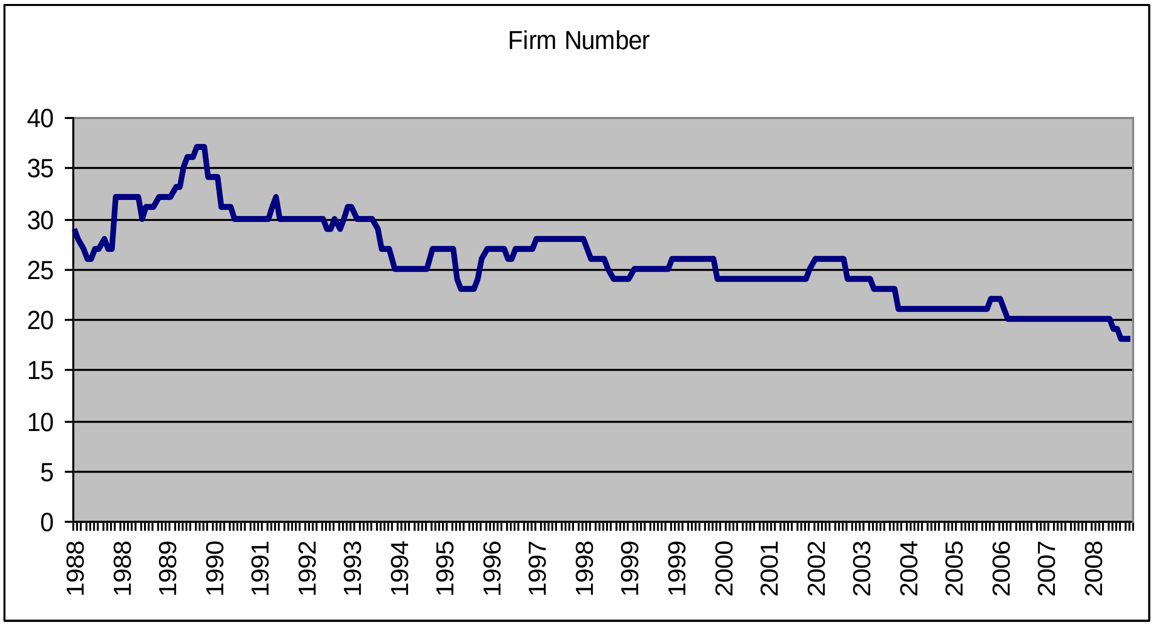

Figure 4b: **Number of Catfish Processors (number of plants)**

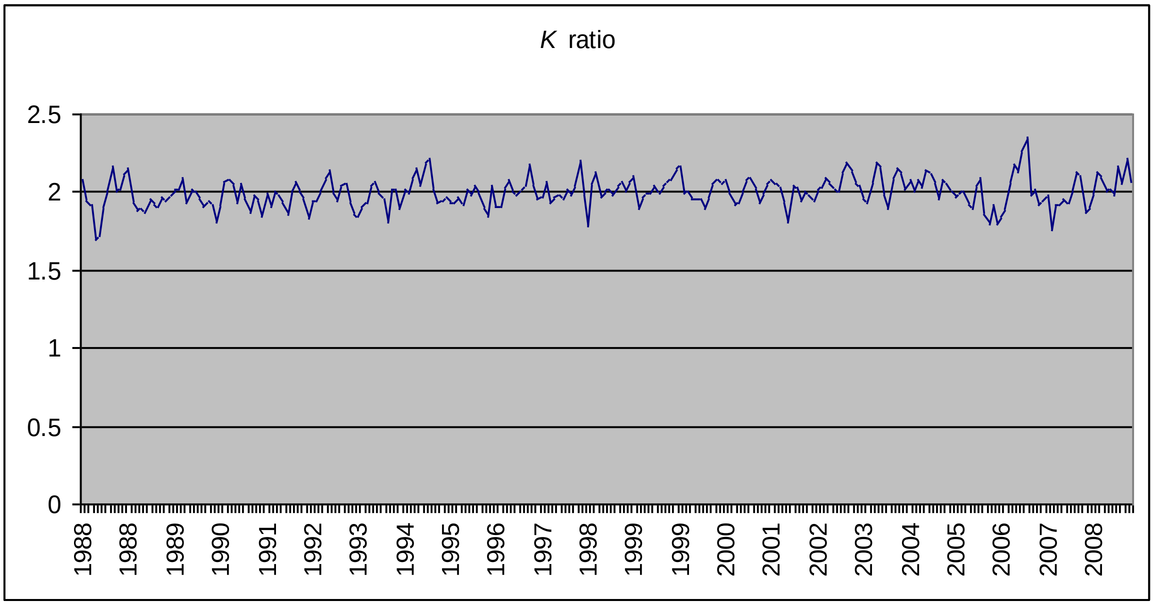

Figure 5: **Production Ratio (Live Catfish Volume/Processed Catfish Volume)**

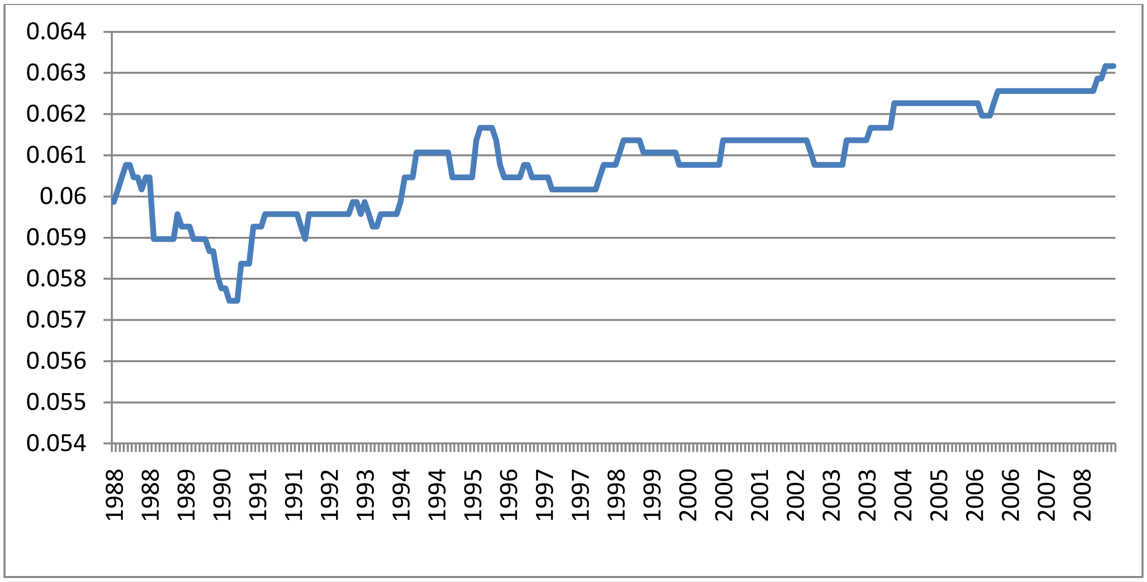

Figure 6: **Industry Conjectural Variation Elasticity**

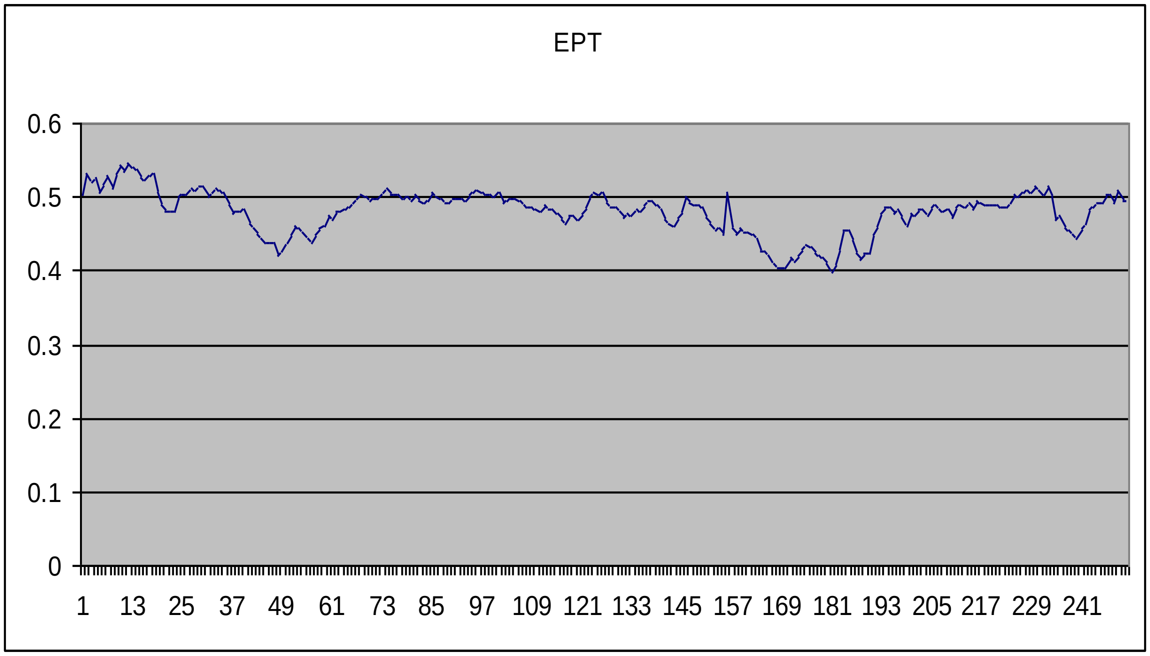

Figure 7: **Elasticity of Price Transmission**

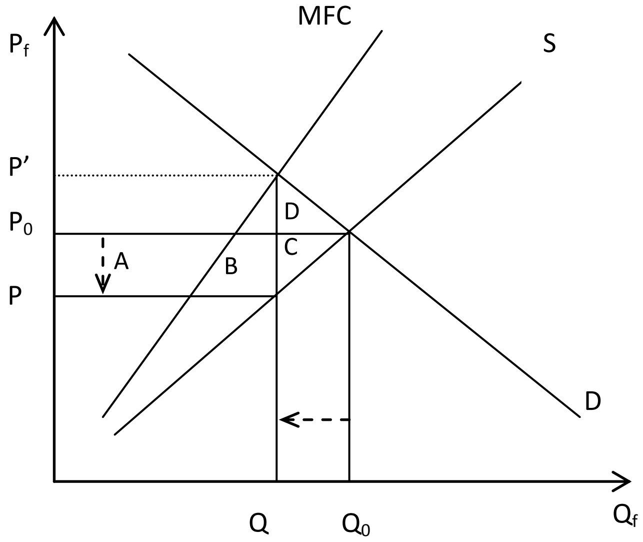

Figure 8: **Loss of Producer Surplus due to Oligopsony at Farm Market**

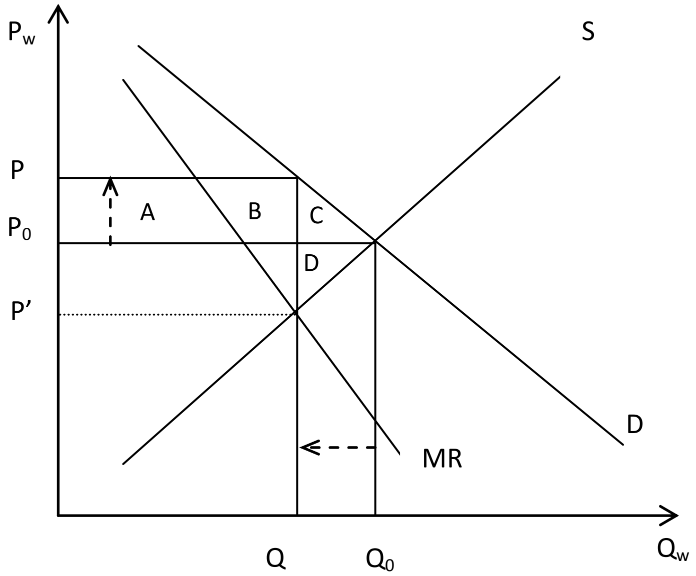

Figure 9: **Loss of Consumer Surplus due to Oligopoly at Wholesale Market**

CHAPTER 3: PRODUCT DIVERSIFICATION, RISK TRANSFER IN U.S. FARM RAISED CATFISH

1. Introduction

Risk is an unavoidable element in agriculture and agri-business enterprises. Uncertainty is the lack of knowledge or predictability about a future event due to the randomness of that event. Risk is the possibility of adversity or loss to producers due to the uncertainty of unfavorable events (Harwood et al. 1999). In agricultural production, there are two main types of risks, production risks and market risk. Production and yield risks relate to uncertainties in weather, disease, disaster, and improvement of technology which may increase output efficiency, but may increase risk also. Market risk relates to oscillation of input and output prices. Price risks refer to changes in price after farmers have made commitments to produce a certain amount of agricultural products. Agricultural production is often lengthy; therefore, there are possibilities that prices may change during the production period. The present chapter will analyze the effects of market risks, which originate from the shocks in factor demand at the catfish processing level on the U.S. catfish farm production.

Previous studies on risks in the U.S. catfish industry include Branch and Tilley (1991), Losinger (2006), Soto & Kazmierczak (2000), Neira and Quagrainie (2007). The production risk often detected in the U.S. catfish farming industry is related to the off-flavor problem which catfish take up bad taste from the environment. Off-flavor and input price risk negatively affect farmers' harvesting decision of catfish (Branch and Tilley, 1991). In contrast, output price risk positively affects catfish producers' decision on harvesting volume since lower output price discourages producers to hold on-farm live catfish inventories due to low expected future profitability and high cost of keeping live catfish (Branch and Tilley, 1991). Losinger (2000) finds that farm size and pond size are significant influences on the expected mean catfish yield. Larger farm sizes have a competitive advantage over smaller farm sizes in both aspects of higher yield and lower variance of yield because larger farms are more specialized in catfish production, while smaller catfish farms may be involved in many other income earning activities. Larger pond size has higher effects on variance of catfish yield. Therefore, larger farms with greater numbers of small ponds are less prone to risk due to the likelihood of having pond free of diseases and off-flavor (Losinger, 2000). Similarly, Soto and Kazmierczak (2000) show that the single-batch production systems with small size farms are the most inefficient production type in terms of high risks in yield and net returns. Neira and Quagrainie (2007) use a principal-agent model to examine the risk behaviors among catfish producers and processors. They find that catfish processors do not shift market risks to catfish producers. However, producers are paying high premiums by receiving lower prices for their live catfish. Neira and Quagrainie (2007) also find no evidence of production risk shifting from farmers to processors.

In the U.S. catfish processing industry, there were dramatic changes in the product forms. The industry was once selling only fresh whole fish. The frozen products came in with new technology for refrigeration. Fillet product was rapidly developed in the 1990s. And recently, steak and nugget have been promoted by processors. The diversification process of product forms in the U.S. catfish processing industry raises some research questions: What are the incentives for processors to diversify their products? How is product diversification related to risks in the U.S. catfish industry? Does product diversification in catfish processing have any impact on the U.S. catfish producers at the farm level? To address these questions the study objectives are numerated: (1) to investigate motivations of product diversification and its impacts on risk, profitability of the U.S. catfish processing industry; (2) to investigate the effects of different processed catfish products, such as whole fish, fillet, steak, fresh vs. frozen, on the behavior of the U.S. catfish producers regarding risk and supply.

The present study proceeds with the following sections: (1) literature review discusses the current research on product diversification and production risk, and the linkage of risks in a vertical marketing chain; (2) A theoretical model lays out a multi-output production function with risks, and elaborates the transmission of risk from output to input market at processing level in order to explain the motivation of product diversification and its impact on profitability at different marketing stages; (3) Empirical analysis is then conducted to generate the results and discussion of the results; (4) Finally, summary and concluding section highlights the main findings.

2. Literature Review

Farmers like other business people may accept risk if it relates to a chance of earning profits. Higher profits are often associated with higher risks. Risk management involves two main aspects, first, anticipation of unfavorable events, and the probability of its occurrence; second, taking actions that reduce the adversity and loss when the unfavorable event occurs (Patrick, 1992). Responses to risks include hedging to narrow the range of possible unfavorable outcomes, and insurance to pay for loss when an unfavorable event occurs. Making decisions in a risky environment is more difficult than making decisions when one knows what outcomes are expected. In a risky environment, decision making requires anticipation about risk, attitude toward risk, ability to bear risk, and formulation about expectation of the future. Stabilization of agricultural product prices is a major concern to market participants because of random fluctuation in supply and demand of agricultural commodities (Flåm et al. 2009).

Branch and Tilley (1991) investigated the influences of production and price risks on the harvesting decision made by U.S. catfish growers and found that the principal risk in U.S. catfish production is off-flavor problem; fish pick up distasteful flavors from the pond environment. Another risk factor is price risk which involves the unexpected rise in input price, such as feed and fingerling prices, and the unexpected downward change in output price. Branch and Tilley (1991) estimated a farm supply response function with inclusion of production and price risks. Production risk is computed as the probability of off-flavor problem. They used the unmarketable fish quantity for each month to compute probability distribution with its mode in September of each year. Input price risk is computed by comparing current feed price with expected feed price. Expected feed price is a weighted average of feed price from the immediate past. If current feed price is higher than expected price, then risk is assigned as the square of that difference. If current price is lower than expected price, then risk is zero. Similarly output price risk is zero, if current output price is higher than expected output price, and is the square of the difference of current output price, if it is lower than the expected output price. Branch and Tilley (1991) found that the occurrence of off-flavor has strong, negative impacts on harvesting decision of catfish producers. Producers try to harvest during the time before the highest probability of off-flavor occurring in September. Input price risk also has a negative effect on live catfish supply. Input price risk has a negative effect on producers' decision to harvest. Output price risk, on the other hand, has a positive effect on producers' decision to harvest. Branch and Tilley (1991) argued that in the presence of price risks, producers are unwilling to keep live catfish as pond inventory. Therefore, price risks should increase current harvesting/supply. In conclusion, Branch and Tilley (1991) found that harvest of food-size catfish is significantly affected by falling output price and occurrence of off-flavor. The inclusion of risk factor into the supply equation estimation reduces the level of supply responsiveness. Supply price elasticities were 0.6 and 0.578 without and with consideration of risk factor into the supply estimation.

Losinger (2006) used data from a survey of 571 catfish farmers in the U.S. in 1997, and applied the Just-Pope production function to separate the expected mean and variance of output. He argues that farmers' concerns are not only profit maximization, but also the minimization of profit variance. The results show that larger farm size reduces the variance in production output per acre (yield). Losinger (2000) also found that farm size has a positive effect on mean of yield. Losinger argues that larger farms have a competitive advantage over smaller farms in both aspects of higher yield and lower variance of yield because larger farms are more specialized in catfish production, while smaller catfish farms may be involved in many other income earning activities. Losinger (2006) found that pond size has a positive effect on the variance of catfish yield.

Losinger argued that a larger farm with greater number of smaller ponds will likely have ponds free of disease and off-flavor problems. In general, larger ponds make it more difficult for farmers to control water quality and pond management. Therefore, larger ponds have a higher risk of disease and off-flavor.

Soto and Kazmierczak (2000) analyzed the price and yield risks faced by catfish producers, and how these risks affect net returns of different farm sizes and production technologies, such as single-batch and multiple-batch production systems. They used computer software programs to generate data on catfish yield and net returns for different farm size and production systems. Soto and Kazmierczak (2000) estimated empirical probability distribution functions for price, yield, and net returns. The results indicated that probability distribution of yield and catfish price affects the shape of the distribution of residual net returns. They found that the single-batch production system for small size farms was the most inefficient production system.

Neira and Quagrainie (2007) assessed risk shifting between catfish farmers and catfish processors in the U.S. Processors largely impose the terms of trade when buying live catfish from farmers, such as size of fish and quality requirement like off-flavor. Neira and Quagrainie (2007) use principal-agent model to examine the risk behavior of catfish processors. They found that catfish processors do not shift risk to catfish farmers. Neira and Quagrainie (2007) argued that catfish farmers are paying high premiums by receiving lower prices for their live catfish. Neira and Quagrainie (2007) also found no evidence of production risk shifting from farmers to processors. Delivery right does not have effects on risk shifting in the U.S. catfish industry, and catfish processors are not ready to involve farmers in the investment on developing/producing higher valued products. They also found a declining trend in the constant absolute risk aversion of catfish farmers, indicating that farmers may be willing to accept more risk from marketing their products in anticipation of higher profits.

3. Theoretical Model

Producers maximize expected utility $EU(W_0 + \mathbf{p'y} - \mathbf{r'x})$, where W_0 is initial wealth, $\mathbf{y}$ is a vector of product outputs, $\mathbf{y} = (y_1, y_2 \ldots y_m)$; and $\mathbf{p}$ is a vector of output price, $\mathbf{p} = (p_1, p_2 \ldots p_m)$; $\mathbf{x}$ is a vector of inputs, $\mathbf{x} = (x_1, x_2 \ldots x_n)$; $\mathbf{r}$ is a vector of input prices, $\mathbf{r} = (r_1, r_2 \ldots r_n)$; $\mathbf{p}$ and $\mathbf{r}$ are random variables, and has a joint probability distribution function (PDF) of $f(\mathbf{p}, \mathbf{r})$. The expected utility is:

(1) $EU(W_0 + \mathbf{p'y} - \mathbf{r'x}) = \int U(W_0 + \mathbf{p'y} - \mathbf{r'x})\, f(\mathbf{p}, \mathbf{r})\, d\mathbf{p}\, d\mathbf{r}$.

Taylor series expansion shows that expected utility is a function of moments of the probability distribution function $f(\mathbf{p}, \mathbf{r})$: $EU(W_0 + \mathbf{p'y}) = g(M_1, M_2 \ldots M_k)$, where $M_1, M_2 \ldots M_k$ are the first k moments of the joint PDF function $f(\mathbf{p}, \mathbf{r})$.

Producers are risk averse when $U' > 0$ and $U'' < 0$. The problem of expected utility maximization is posed as:

(2) $\text{Max}\ [EU(W_0 + \mathbf{p'y} - \mathbf{r'x}) \mid F(\mathbf{x}, \mathbf{y}) = 0]$

where, $F(\mathbf{x}, \mathbf{y}) = 0$ is the implicit production function with multi-outputs and multi-inputs. Solving the maximization problem, we obtain the optimal output supply and input demand:

(3) $x_i = x_i^*(\mathbf{p}_e, \mathbf{r}_e, \boldsymbol{\sigma}_p, \boldsymbol{\sigma}_r, W_0)$, $\quad i = 1,\ldots,n$

(4) $y_i = y_i^*(\mathbf{p}_e, \mathbf{r}_e, \boldsymbol{\sigma}_p, \boldsymbol{\sigma}_r, W_0), \qquad i = 1,...,m$

where, $\mathbf{p}_e$ is a vector of expected means of output prices, $\mathbf{r}_e$ is a vector of expected means of input prices, $\boldsymbol{\sigma}_p$ is a matrix of higher-order moments of output price distributions, $\boldsymbol{\sigma}_r$ is a matrix of higher-order moments of input price distributions.

In the U.S. catfish processing industry, outputs include whole fish, fillet, and other types such as steak and nugget, both in fresh and frozen forms. Input in catfish processing include live catfish, labor, energy, and machines. This study is concerned about the demand for farm raised catfish, and investigates the effects of changes in the structure of processed products and its prices on the demand for live catfish. The argument is that when processors diversify their product forms they are seeking for higher expected profits as well as lower variability of their expected profit. Product diversification at the processing level will result in a higher factor demand for farm raised catfish, and will improve the stability of that factor demand. In other words, product diversification at processing will reduce the factor demand shock, and hence reduce output price risk for catfish producers.

Live catfish is the most single important input in catfish processing. Processors buy farm catfish from producers and process them into different product forms. The factor demand for live catfish at the processing market is, i=1:

(5) $x_1 = x_1^*(\mathbf{p}_e, \mathbf{r}_e, \boldsymbol{\sigma}_p, \boldsymbol{\sigma}_r, W_0)$

The expected signs of $\mathbf{p}_e$ are positive since higher output price implies higher potential profitability level; therefore, processors will demand more farm catfish as an input to increase their production of value added products. The expected signs of $\mathbf{r}_e$ are negative because higher input price will reduce the profitability of processing, and hence processors will demand less factor input. In catfish processing, the substitutabilities between farm catfish and other factors, such as labor, energy, and machines are almost absent. The weak substitutabilities confirm the expected negative signs in $\mathbf{r}_e$. Both $\boldsymbol{\sigma}_p$ and $\boldsymbol{\sigma}_r$ are expected to have negative effects on the factor demand, assuming catfish processors are risk averse.

In the present study, we are concerned mainly about the effects of output diversification and its price risks on live catfish factor demand and how those effects will be transmitted into market risk at the farm level. Theory predicts that price and price variability at the processor level affect price variability and supply at the farm level. It is also propounded that shocks in factor demand for catfish, or fluctuation in catfish demand will affect catfish supply and producer price. The higher fluctuation in the catfish factor demand will discourage catfish producers to produce more catfish. We will test the above hypothesis employing a two stage procedure. The first stage will involve the estimation of catfish factor demand at the processing level, the market shocks in factor demand will be captured in the estimated residual generated in that estimation. The second stage involves the estimation of catfish producers' supply response in the presence of market risk or shocks in catfish factor demand. The general farm supply function in the second stage is specified using a normalized profit function approach:

$$(6) \qquad Q = S(\mathbf{r}^*, \mathbf{Z}, \mathbf{p}_e, \boldsymbol{\sigma}_p)$$

where, Q is catfish farm supply volume, $\mathbf{r}^*$ is a vector of normalized input prices in catfish farm production, **Z** is a vector of fixed factors in catfish production, $\mathbf{p}_e$ and $\boldsymbol{\sigma}_p$ are vectors of expected means and variability of output prices at processor market level. The expected signs of **r*** are negative, **Z**'s are positive, $\mathbf{p}_e$'s are positive, and $\boldsymbol{\sigma}_p$'s are negative. One of the objectives of this study is to test the effects of product diversification at processing level on the risk response of producers at the farm level. Therefore, the second stage will be estimated using a three-stage procedure proposed by Just and Pope (1979).

4. Empirical Analysis

The empirical analysis involves estimations of (5) and (6). Equation (5) is processors' factor demand function of farm raised catfish, and it captures the effects of output price risks on the fluctuation of factor demand of farm catfish. The equation (6) is the farm catfish supply function; it describes producers' behavior or farm supply response under uncertainties from prices as well as from fluctuation from factor demand. Data used to estimate (5) and (6) are monthly, available prices from January 1988 to December 2008. Data on catfish are collected from USDA's various reports. Data on price indices are from The Bureau of Labor Statistics. Other data are from The Bureau of Economic Analysis (BEA), and U.S. Census. The empirical model of catfish factor demand (5) is specified in the log-linear functional form:

$$\text{(7)} \quad \ln(\text{farmvolume}_t) = b_0 + b_1{*}\ln(E(\text{farmprice}_t)) + b_2{*}\ln(E(\text{gasprice}_t)) + b_3{*}\ln(E(\text{interest}_t)) + b_4{*}\ln(E(\text{wage}_t)) + b_5{*}\ln(E(\text{P\_wholefish\_fresh}_t)) + b_6{*}\ln(E(\text{P\_fillet\_fresh}_t)) + b_7{*}\ln(E(\text{P\_other\_fresh}_t)) +$$

$$b_8 * \ln(E(P\_wholefish\_frozen_t)) + b_9 * \ln(E(P\_fillet\_frozen_t)) +$$

$$b_{10} * \ln(E(P\_other\_frozen_t)) + b_{11} * \ln(E(vfarmprice_t)) + b_{12} * \ln(V(gasprice_t)) +$$

$$b_{13} * \ln(V(interest_t)) + b_{14} * \ln(V(wage_t)) + b_{15} * \ln(V(P\_wholefish\_fresh_t)) +$$

$$b_{16} * \ln(V(P\_fillet\_fresh_t)) + b_{17} * \ln(V(P\_other\_fresh_t)) +$$

$$b_{18} * \ln(V(P\_wholefish\_frozen_t)) + b_{19} * \ln(V(P\_fillet\_frozen_t)) +$$

$$b_{20} * \ln(V(P\_other\_frozen_t)) + b_{21} * \ln(GDP_t) + b_{22} * \ln(POP_t) + e$$

where, E(x) is symbol for expectation of variable x, V(x) denotes the conditional variance of variable x. The most popular derivations of expectation and conditional variance are developed by Just (1974) using the adaptive expectation model of price popularized by Nerlove (1958) in analysis of agricultural supply. The formulas of expectation and conditional variance of price are (Just, 1974):

$$E(p_t) = \theta_p \sum_{k=0}(1 - \theta_p)^k p_{t-k-1}$$

$$V(p_t) = \delta_p \sum_{k=0}(1 - \delta_p)^k [p_{t-k-1} – E(p_{t-k-1})]^2$$

where, θ_p and δ_p are scalars, ranging from 0 to 1. Factor demand for live catfish is negatively dependent on prices of inputs in catfish processing, such as price of live catfish, wage, price of fuel, and interest rate symbolizing the opportunity cost of capital. Processed catfish products include whole fish, fillet, and other products in both fresh and frozen forms. Initial wealth of catfish processor is, however unknown, however, GDP and population is used as a proxy for national wealth. The estimation results of (7) are presented in Table 1. All input prices are expected to have a negative relationship with factor demand of catfish. However, expectations of input prices are not significant, except for wage. Expectations of output prices are expected to have a positive coefficient. However, only estimation of coefficients of prices of fresh whole fish and frozen fillet are positive and statistically significant. A one % increase in prices of fresh whole fish and frozen fillet results in a 0.73% and 0.79%, respectively, increase in factor demand for catfish. In contrast, fresh fillet and frozen whole fish have unanticipated negative effects on factor demand for live catfish. Variability of frozen fillet has a significant negative effect on catfish factor demand (-0.042). All estimations of conditional variances of other output prices are not significant. The results show that fresh whole fish and frozen fillet are important product forms that affect catfish factor demand. Figure 1 indicates that fresh whole fish was a dominant product form in the past and is decreasing over time. Frozen fillet share is increasing fast and accounts for the largest share in volume of processed catfish products at present.

The empirical model for catfish farm supply response to risk (6) follows the specification of farm supply function derived from a normalized profit function approach (Jorgenson and Lau, 1974; Yotopoulos and Lau, 1979), and includes expectations and conditional variances of processed product prices to test for the effect of risk transfer from processed to farm market. The empirical model of catfish farm supply response to risk is:

$$
\begin{aligned}
(8)\quad & \ln Farmvolume = \ln(1 - \alpha_1 - \alpha_2 - \alpha_3) + \alpha_0\, Year + \alpha_1 \ln(E(Feedprice^*) + \alpha_2 \\
& \ln(E(Gasprice^*) + \alpha_3 \ln(E(Capitalprice^*) + \alpha_4 \ln(V(Feedprice^*) + \alpha_5 \\
& \ln(V(Gasprice^*) + \alpha_6 \ln(V(Capitalprice^*) + \beta \ln Farmsize + \\
& c_1{*}\ln(E(P\_wholefish\_fresh)) + c_2{*}\ln(E(P\_fillet\_fresh)) + c_3{*}\ln(E(P\_other\_fresh))
\end{aligned}
$$

$$+ c_4*\ln(E(P\_wholefish\_frozen)) + c_5*\ln(E(P\_fillet\_frozen)) + c_6*\ln(E(P\_other\_frozen)) + c_7*\ln(V(P\_wholefish\_fresh)) + c_8*\ln(V(P\_fillet\_fresh)) + c_9*\ln(V(P\_other\_fresh)) + c_{10}*\ln(V(P\_wholefish\_frozen)) + c_{11}*\ln(V(P\_fillet\_frozen)) + c_{12}*\ln(V(P\_other\_frozen)) + e$$

where, Feedprice*, Gasprice*, and Capitalprice* are normalized input prices for catfish farm production. Normalized prices are obtained by dividing input price by catfish farm price. The estimation of (8) follows the three-stage procedure proposed by Just and Pope (1979). The estimation of Stage I is presented in Table 2a. The results show that normalized input prices have negative effects on catfish supply as anticipated. The farm supply elasticity is $-(\alpha_1 + \alpha_1) = 0.22$. Estimations of conditional variances of normalized input price have negative effects on supply as expected (α_3 and α_4), except for capital price (α_6), indicating that risks reduce farm supply. Fresh whole fish and frozen fillet have positive effects on catfish farm supply. If prices of fresh whole fish and frozen fillet increase, catfish producers will supply more. Fresh fillet and frozen whole fish have negative effects on farm catfish supply. Most of the conditional variances in product prices at processor market level have no impacts on farm catfish supply. The result implies that market risks at processor market level are not transferred to catfish producers. The result conforms to the finding of Neira and Quagrainie (2007). The Stage II is estimated using the residuals in Stage I as a dependent variable of the same set of independent variables in Stage I. The estimation of Stage II is presented in Table 2b. Predicted values of the independent variables in Stage II are obtained. Stage III is a repeat estimation of Stage I after weighting all variables with the predicted values obtained in Stage II. The estimation results are presented in Table 2c. The results show that higher expectations in fillet prices will increase catfish farm supply. In the mean time, expectations of whole catfish prices have negative effects on farm supply. Output price risks or conditional variances in prices of processed catfish products mostly have negative effects on farm supply as anticipated, except for fresh whole fish and fresh fillet.

5. Summary and Conclusion

The present study discusses a theoretical model that links the price risks at processor market level to farm supply response. Processors' price risks will affect factor demand for farm raised catfish. In turn, the fluctuation in factor demand will have some influence on the catfish producers' behaviors, because factor demand fluctuation is equal to market risks to catfish producers. Derived factor demand and farm supply of catfish with price risks are estimated. Expectations of input/output price at processor market level have negative/positive effects on factor demand for farm raised catfish. Conditional variance of prices have negative effects on factor demand for farm catfish, in other words, price risks reduce processors' demand for farm raised catfish.

The effects of price risks for catfish processing on catfish farm supply are examined using the three-stage procedure by Just and Pope (1979). The results show evidence that price risk at processing reduces catfish farm supply. In terms of product forms, the results show that fillet have positive effects on farm supply, if processors produce more catfish, or price of fillet increases, farm supply will increase. Risks of fillet price have negative effects on catfish farm supply. In contrast, whole fish have a negative relationship on farm supply. The present study has two limitations, the lack of theoretical and empirical analysis of product diversification and its effects on processing and farm market; second, factor demand and farm supply of catfish should be placed in a market equilibrium framework in order to completely analyze the effects of shocks and fluctuations in factor demand on catfish farm supply.

Appendix 3

Table 1: Estimation of Factor Demand for Farm Raised Catfish

Variable	Estimate	t Value	Pr > |t|
Constant	-31.8064	-4.11	<.0001
ln(E(Farmprice))	-0.18909	-1.04	0.2981
ln(E(Gasprice))	-0.0431	-0.69	0.4917
ln(E(Interest))	-0.0373	-0.6	0.5501
ln(E(Wage))	-2.01888*	-1.9	0.0583
ln(E(Price_wholefish_fresh))	0.73301***	3.07	0.0024
ln(E(Price_fillet_fresh))	-1.53269***	-3.42	0.0008
ln(E(Price_other_fresh))	-0.08197	-0.36	0.7173
ln(E(Price_wholefish_frozen))	-0.63111**	-2.2	0.029
ln(E(Price_fillet_frozen))	0.792654*	1.89	0.0608
ln(E(Price_other_frozen))	0.126796	0.9	0.3694
ln(V(Farmprice))	0.007637	0.62	0.5387
ln(V(Gasprice))	-0.07752***	-4.16	<.0001
ln(V(Interest))	0.012188**	2.11	0.0364
ln(V(Wage))	0.055837*	1.91	0.0578
ln(V(Price_wholefish_fresh))	0.022441	1.1	0.2718
ln(V(Prie_fillet_fresh))	0.00868	0.62	0.5369
ln(V(Price_other_fresh))	-0.00877	-0.48	0.6323
ln(V(Price_wholefish_frozen))	-0.01983	-1.01	0.3144
ln(V(Price_fillet_frozen))	-0.04238***	-3.2	0.0016
ln(V(Price_other_frozen))	0.007772	0.48	0.6335
ln(GDP)	0.960599	1.42	0.1584
ln(POP)	7.935496***	4.05	<.0001
DW	1.3198		
Shapiro-Wilk p-value	0.5871		

*** significant at 99%; ** significant at 95%; * significant at 90%

Table 2a: **Stage I - Estimation of Catfish Farm Supply Response to Risk**

Variable	Estimate	t Value	Pr > |t|
year	0.004751	21.88	<.0001
ln(E(Feedprice*)	-0.12575*	-1.82	0.0697
ln(E(Gasprice*)	0.041988	1.2	0.2317
ln(E(Capitalprice*)	-0.09404***	-2.64	0.009
ln(V(Feedprice*)	-0.02213**	-2.25	0.0254
ln(V(Gasprice*)	-0.01933**	-2.09	0.0379
ln(V(Capitalprice*)	0.015291*	1.61	0.1087
lnFarmsize	0.502421***	7.74	<.0001
ln(E(Price_wholefish_fresh))	0.331868*	1.78	0.077
ln(E(Price_fillet_fresh))	-1.75031***	-3.9	0.0001
ln(E(Price_other_fresh))	-0.36147**	-2.15	0.0328
ln(E(Price_wholefish_frozen))	-0.42659*	-1.68	0.0949
ln(E(Price_fillet_frozen))	0.860314**	2	0.0468
ln(E(Price_other_frozen))	-0.02678	-0.23	0.8175
ln(V(Price_wholefish_fresh))	0.036108**	2.32	0.0213
ln(V(Price_fillet_fresh))	0.008582	0.7	0.4824
ln(V(Price_other_fresh))	0.002575	0.15	0.8798
ln(V(Price_wholefish_frozen))	-0.01172	-0.93	0.3521
ln(V(Price_fillet_frozen))	0.002234	0.17	0.8688
ln(V(Price_other_frozen))	0.017781	1.41	0.1613
R^2-adjusted	0.8364		
DW	1.4253		
Shapiro-Wilk p-value	0.6990		

Note: * at variables mean ‘normalized’ input price; at the estimates: *** significant at 99%; ** significant at 95%; * significant at 90%

Table 2b: **Stage II - Estimation of Risk Component in Catfish Farm Supply**

Variable	Estimate	t Value	Pr > |t|
year	-0.00129	-0.4	0.6895
ln(E(Feedprice*)	-0.15186	-0.16	0.8754
ln(E(Gasprice*)	-0.31727	-0.51	0.6099
ln(E(Capitalprice*)	0.10601	0.19	0.8468
ln(V(Feedprice*)	0.157411	1.09	0.277
ln(V(Gasprice*)	0.345616**	2.46	0.0147
ln(V(Capitalprice*)	-0.30253**	-2.34	0.0203
lnFarmsize	0.327485	0.34	0.7332
ln(E(Price_wholefish_fresh))	1.592292	0.53	0.5986
ln(E(Price_fillet_fresh))	-3.08289	-0.49	0.6227
ln(E(Price_other_fresh))	-1.15356	-0.43	0.6685
ln(E(Price_wholefish_frozen))	-0.00999	0	0.9978
ln(E(Price_fillet_frozen))	0.522985	0.09	0.9317
ln(E(Price_other_frozen))	2.598069	1.49	0.1369
ln(V(Price_wholefish_fresh))	-0.17348	-0.79	0.4282
ln(V(Price_fillet_fresh))	-0.1439	-0.82	0.4107
ln(V(Price_other_fresh))	0.194239	0.85	0.394
ln(V(Price_wholefish_frozen))	-0.00611	-0.03	0.9748
ln(V(Price_fillet_frozen))	0.397118**	1.98	0.0496
ln(V(Price_other_frozen))	0.036177	0.18	0.8566
DW	2.1082		
Shapiro-Wilk p-value	<.0001		

Note: * at variables mean ‘normalized’ input price; at the estimates: *** significant at 99%; ** significant at 95%; * significant at 90%

Table 2c: **Stage III - Estimation of Catfish Farm Supply Response to Risk**

Variable	Estimate	t Value	Pr > |t|
year	0.011614	5.52	<.0001
ln(E(Feedprice*)	0.073023	0.61	0.5458
ln(E(Gasprice*)	0.251637**	2.45	0.015
ln(E(Capitalprice*)	-0.51204***	-7.88	<.0001
ln(V(Feedprice*)	-0.16789***	-5.48	<.0001
ln(V(Gasprice*)	-0.26655***	-5.08	<.0001
ln(V(Capitalprice*)	0.265725***	6.07	<.0001
lnFarmsize	1.127752***	11.64	<.0001
ln(E(Price_wholefish_fresh))	-1.67425***	-6.13	<.0001
ln(E(Price_fillet_fresh))	2.401794***	3.11	0.0021
ln(E(Price_other_fresh))	2.100268***	6.28	<.0001
ln(E(Price_wholefish_frozen))	-3.46952***	-12.17	<.0001
ln(E(Price_fillet_frozen))	1.738739**	2.48	0.0139
ln(E(Price_other_frozen))	-1.38581***	-3.42	0.0008
ln(V(Price_wholefish_fresh))	0.112199***	2.88	0.0044
ln(V(Price_fillet_fresh))	0.134697***	4.97	<.0001
ln(V(Price_other_fresh))	-0.20185***	-5.53	<.0001
ln(V(Price_wholefish_frozen))	-0.05812***	-2.78	0.006
ln(V(Price_fillet_frozen))	-0.3102***	-5.52	<.0001
ln(V(Price_other_frozen))	-0.03025	-1.14	0.2556
R^2-adjusted	0.9984		
DW	1.1799		
Shapiro-Wilk p-value	0.8915		

Note: * at variables mean ‘normalized’ input price; at the estimates: *** significant at 99%; ** significant at 95%; * significant at 90%

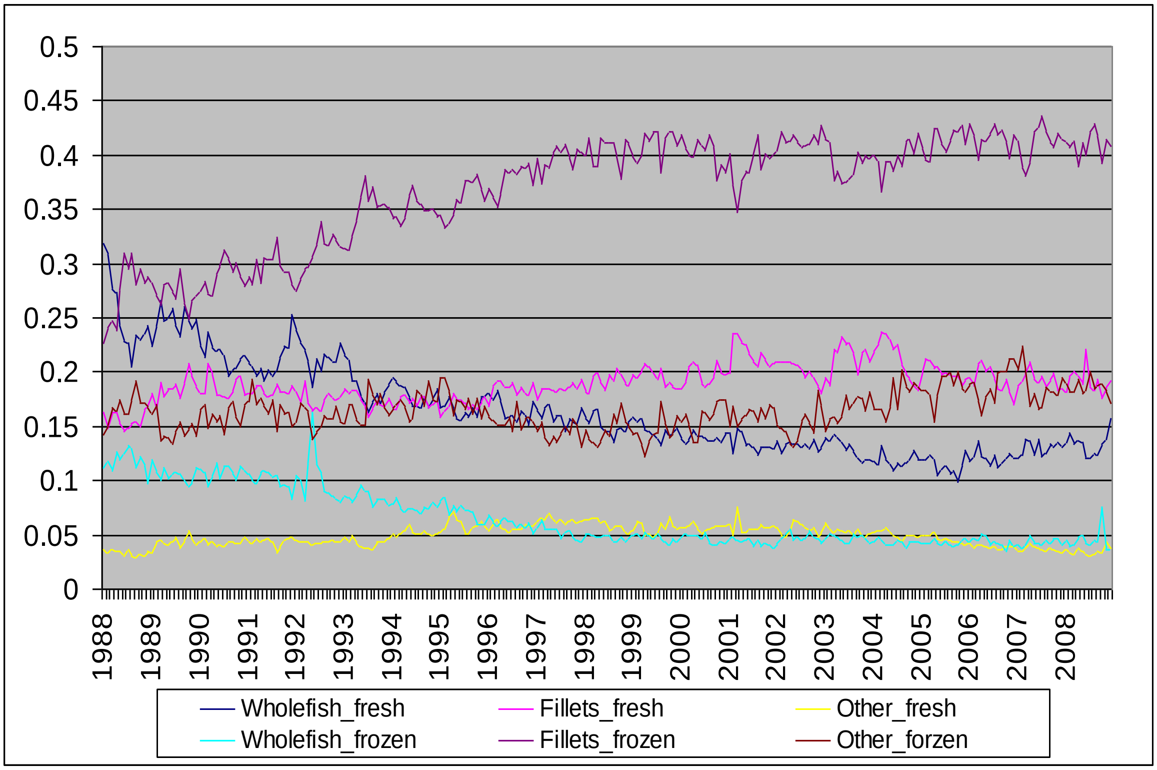

Figure 1: Market Share of Different Processed Catfish Products (%)

CONCLUSION

In this dissertation, I have investigated the supply response, price transmission, market power, and risks in U.S. farm raised catfish and catfish processing industry. The short-run catfish supply elasticities are between 0.23 and 0.28, and long-run supply elasticities are between 0.80 and 2.1 depending on estimation methods. Only 8.5% out of 72.7% of the U.S catfish production expansion between 1988 and 2008 is attributed to technical change. The U.S. catfish industry is at the stage of decreasing returns to scale, and an increase of 1% in all input factors causes farm output to increase by 0.34 %. In the short-run, catfish producers mainly vary production yield in response to price changes. In contrast, catfish acreage is more responsive to the price change in the long-run. The risk model in the catfish supply shows that variations of profitability negatively affect farm supply. The variations or risks of farm supply are mainly determined by non-price risk factors. The U.S. catfish farm supply variation is decreasing over the years. U.S. catfish producers respond less to profit incentives in the presence of risk.

The short-run and long-run elasticities of price transmission are 0.40 and of 0.60. Price transmission is asymmetric, and about 62% of positive price transmission and 40% of negative price transmission are realized spontaneously. The results show that asymmetry in price transmission is a short-run matter. Over the long-run, error correction will correct the asymmetric transmission of price. Whole fish product has the largest elasticity of price transmission, and fillet has the smallest. The industry conjectural variation elasticity is 0.06. The number of catfish processors has a negative effect on the industry conjectural variation elasticity. Conjectural variation implies the ability to manipulate market quantities supplied or demanded by one or a group of market agents. It is the direct information describing the intensity of market power.

The oligopoly power index is 0.11, and the oligopsony power index is 0.50. Empirical evidence shows that market power negatively affects the elasticity of price transmission. Market power is not a decisive factor in the asymmetry of price transmission. Processors exert oligopsony power and forces catfish farm gate price downward estimated between $0.05 and $0.37 per pound. Processors also exert their oligopoly power, and are able to charge a higher price to consumers of an extra of $0.07 to $0.25 per pound.

Price risks at the processing market affect factor demand for farm raised catfish. In turn, the fluctuation in factor demand will have some influence on the catfish producers' behaviors. Expectations of input/output price at the processing market level have negative/positive effects on factor demand for farm raised catfish. Conditional variances of prices have negative effects on factor demand for farm raised catfish. In other words, price risks reduce processor demand for farm raised catfish. The effects of price risks at catfish processing on catfish farm supply are examined. The results show evidence that price risks at processing reduce catfish farm supply. In terms of product forms, the results show that fillet have positive effects on farm supply, if processors produce more fillet, or price of fillet increases, farm supply will increase. Risks of fillet price have negative effects on farm raised catfish supply. In contrast, whole fish have a negative relationship with farm raised catfish supply.

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