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# Dynamic Effects of Grain and Energy Prices on the Catfish Feed and Farm Sectors

**Andrew Muhammad and Hualu Zheng**

This study examines the dynamic effects of grain prices and energy prices on catfish feed prices and the price of food-sized catfish at the farm level. Using the autoregressive distributed lag model and bounds testing procedure, a long-run relationship between feed and farm prices and their determinants was confirmed. Given the effect of corn and soybean meal prices on catfish feed prices, and catfish fish feed prices on farm prices, the long-run responsiveness of feed prices to a percentage increase in U.S. ethanol production is 0.325, and the responsiveness of catfish farm prices is 0.064. Although both feed and farm prices increase with ethanol production, the relatively small responsiveness of farm prices when compared with feed prices suggests that catfish farmers are worse off. Results are conditional on ethanol production causing an increase in grain prices.

*Key Words:* catfish, prices, autoregressive distributed lag (ARDL) model, ethanol, feed, corn, soybeans

**JEL Classifications:** C32, Q11, Q22

The recent increase in catfish feed prices induced by the increase in grain prices has created concerns in the U.S. catfish industry. Corn and soybeans are the primary ingredients in catfish feed in which corn can account for up to 32.1% and soybean meal up to 41.6% of total feed ingredients (Robinson, Li, and Hogue, 2006). Furthermore, feed costs are the primary expense in catfish production, accounting for over 50% of total variable expenses. Wells (2007) indicate that increased grain prices resulted in catfish feed prices increasing by nearly $30 per ton in 2007. Spencer (2008) gives an even greater estimate. He notes that feed that once sold for $250 a ton was selling from $380 to $410 a ton in 2007.

Monthly catfish feed prices ($/ton), #2 yellow corn prices ($/bushel), and soybean meal prices ($/ton) from 1996 through 2008 are presented in Figure 1. Given the importance of corn and soybean meal to catfish feed production, there is a strong relationship among catfish feed, corn, and soybean meal prices. In mid-2004, corn prices peaked at $2.90 and soybean meal prices peaked at $311.50. During this period, catfish feed prices peaked at $310.00. Particularly striking is what occurred in 2008 when corn and soybean meal prices reached highs of $6.55 and $412.25, respectively. During this

Andrew Muhammad is senior research economist, International Demand and Trade Branch, Economic Research Service, U.S. Department of Agriculture, Washington, DC. Hualu Zheng is former M.S. student, Department of Agricultural Economics, Mississippi State University, Mississippi State, MS.

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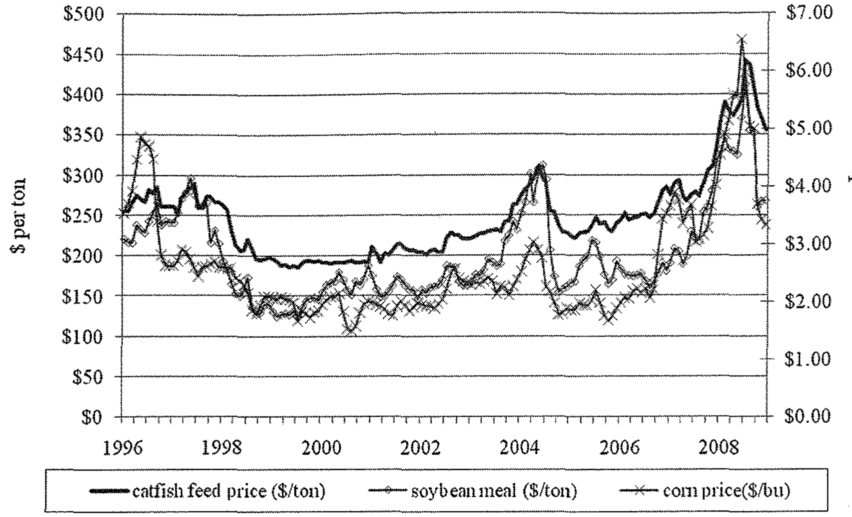


**Figure 1.** Catfish Feed Prices, Corn Price, and Soybean Meal Prices: January 1996–December 2008 (Source: Catfish Feed Prices, National Agricultural Statistical Service; Corn Price and Soybean Meal Prices, USDA, Economic Research Service Feed–Grains Database)

period, catfish feed prices reached a high of $442.00 (Figure 1).

In addition to higher feed prices, catfish farmers have also been challenged by higher energy prices, particularly the price of diesel fuel and gasoline. The increase in fuel prices in 2008 was primarily the result of the increase in crude oil prices. Throughout most of the 1990s, crude oil prices averaged less than $20 per barrel but reached approximately $65 in the summer of 2006 and averaged $59 for the year (Westcott, 2007). In 2008, crude oil prices rose beyond $140 per barrel.

There has been little research on the effects of grain and energy prices on the U.S. catfish sector. This is of particular importance because the increase in corn and soybean prices and the resulting increase in feed prices have caused economic hardship for catfish producers. Streitfeld (2008) in a *New York Times* article notes that many catfish farmers emptied their ponds because of higher feed prices and energy costs. According to the National Agricultural Statistical Service, pond acres dedicated to catfish production decrease from 175,940 acres in 2005 to 146,900 acres by the end of 2008 (Hanson and Sites, 2009). Additionally, farms sales in 2008 were 514.9 million lbs, down 8.7% when compared with the previous year and 24% since 2002 (Table 1).

**Table 1.** Total Farm Sales, Food-Sized Catfish: 2000–2008

| Year | Quantity (million lbs) | Value (million $) | Percent Change Quantity | Percent Change Value |
|---|---|---|---|---|
| 2000 | 633.79 | $ 467.82 | | |
| 2001 | 647.16 | $ 410.49 | 2.11 | −12.25 |
| 2002 | 675.81 | $ 380.05 | 4.43 | −7.42 |
| 2003 | 668.25 | $ 379.63 | −1.12 | −0.11 |
| 2004 | 664.70 | $ 434.26 | −0.53 | 14.39 |
| 2005 | 605.53 | $ 427.81 | −8.90 | −1.49 |
| 2006 | 568.90 | $ 440.90 | −6.05 | 3.06 |
| 2007 | 563.90 | $ 423.74 | −0.88 | −3.89 |
| 2008 | 514.92 | $ 389.29 | −8.69 | −8.13 |

The purpose of this study is to examine the short-run and long-run effects of grain prices (particularly corn and soybeans) and energy prices on catfish feed prices and the price of food-sized catfish at the farm level. We use the autoregressive distributed lag (ARDL) approach and bounds-testing procedure (Pesaran, Shin, and Smith, 2001) to estimate the specified relationships and to determine if a long-run/cointegrating relationship exists between the variables. Unlike standard cointegration methods, this approach allows for testing the existence of long-run relationships between variables of interest without pretesting for unit roots and can be applied to time-series data whether the variables are purely $I(0)$ (integrated of order zero), purely $I(1)$ (integrated of order one), or a combination of the two. Using the relationship between biofuels production and grain prices reported in previous studies, the long-run estimates are used to assess the effects of ethanol production on catfish feed and farm prices.

Dynamic analyses of agricultural commodity markets are well established in the literature owing to such studies as Nerlove (1958) and Muth (1961). Past studies suggest that the responsiveness of agricultural production to changes in prices and other factors may not be instantaneous but partially adjust over several periods as a result of producer expectations, biological production lags, adjustments costs, inventories, and other factors. Mundlak (1966) indicates that adjustment costs in production could results in noninstantaneous movements to market equilibria, and Chavas and Johnson (1982) note that agricultural supply dynamics (and hence price dynamics) may be the result of decisions at each stage of production reducing adjustment possibilities in the following stages. Ferris (2005, p. 100) notes that the actual quantity supplied of an agricultural commodity can differ significantly from farmer intentions as a result of the biological lag in agricultural production coupled with unpredictable supply altering events such as weather, pests, and diseases. Consequently, prices in a given period may not reflect the equilibrium, and reaction to disequilibrium typically occurs in subsequent periods. Lastly, Wang and Tomek (2007) indicate that commodity storability as well as the biological nature of commodity production and the costs of arbitrage could result in autocorrelated, convergent price series.

## U.S. Ethanol Production and Corn Prices

The growth in U.S. ethanol and biofuels production has increased the demand for corn and soybeans and is often cited as the primary cause of the increase in grain prices in 2007 and 2008. Koo and Tayor (2008) developed a global simulation model to evaluate the impact of ethanol production on world corn production. Based on the 2005 Energy Policy Act, the authors assumed that ethanol production in 2007 was 6.5 billion gallons, increasing to 7.5 billion gallons by 2012, and remaining at 2012 levels until 2016. They predicted that corn prices would increase from \$3.65 per bushel in 2007 to \$3.78 in 2008, \$4.40 in 2012, but would settle at \$3.69 in 2016.

Taheripour and Tyner (2008) suggested that the corn price increased from approximately \$2.00 in 2004 to \$6.00 in 2008 could be partitioned into two parts: the increase resulting from the U.S. ethanol subsidy and the increase resulting from higher crude oil prices. They concluded that approximately \$1.00 of the increase was the result of the U.S. ethanol subsidy and \$3.00 resulting from the increase in crude oil prices. It must be noted that this increase could be attributed solely to ethanol because the link between crude oil prices and corn prices did not appear to exist before the enactment of the Energy Policy Act of 2005 (Muhammad and Kebede, 2009).

Park and Fortenbery (2007) developed a system of U.S. corn supply and demand equations focusing on the short-run corn price elasticity associated with U.S. ethanol production. The system was comprised of a single corn supply equation, a set of three corn demand equations, each focused on a specific category of demand: the demand for livestock feed use, exports use, and food, alcohol, and industrial use. Their results showed that corn prices increased with ethanol production, where a 1% increase in ethanol production caused a 0.16% increase in the corn price in the short run. The authors further noted that if ethanol production increased by

100%, to 10 billion gallons in 2008, corn prices would increase by 16%, which is approximately 51 cents per bushel greater than price forecasts by the U.S. Department of Agriculture.

## Autoregressive Distributed Lag Model

Pesaran, Shin, and Smith (2001) derived an alternative cointegration procedure commonly refereed to as the error correction version of the ARDL model and bounds testing procedure. This procedure allows for testing the existence of long-run relationships between variables of interest, which can be applied to time-series data whether the variables are purely $I(0)$, purely $I(1)$, or a combination of the two. With this approach, the short-run and long-run relationships among time-series are captured simultaneously, whereas pretesting for unit roots is not needed. This is particularly beneficial because the existence of unit roots often depends on the testing approach chosen. In using the Augmented-Dickey-Fuller approach, one may conclude that unit roots are present, but when using the Phillips-Perron test, one may conclude the absence of unit roots (Pahlavani, Wilson, and Worthington, 2005). This is particularly important when testing for unit roots in commodity price series. Wang and Tomek (2007) found that unit root tests for commodity prices were sensitive to alternative specifications of the Augmented Dickey-Fuller and Phillip-Perron tests. They further found that test results were particularly sensitive to logarithmic transformation, variable deflation, and chosen lag order and suggest that the evidence favoring unit roots in commodity prices is not strong.

Because pretesting for unit roots is not required, the ARDL model has become quite popular in the literature. Bahmani (2008) estimated the relationship among money demand, income, interest rates, inflation rates, and nominal exchange rates in Middle Eastern countries and tested the stability of the money demand in those countries. Oskooee and Ng (2002) examined long-run money demand in Hong Kong where it was found that there was a long-run relationship among money demand, real income, nominal interest rates, foreign interest rates, and foreign exchange rates. Vita and Abbott (2002) estimated the long-run relationship between savings and investment in the U.S., and Atkins and Coe (2002) investigated the existence of the Fisher effect in Canada and U.S. Pahlavani, Wilson, and Worthington (2005) used the ARDL model to estimate the short- and long-run relationship between gross domestic product, oil and nonoil exports, real capital, real imports, and human capital in Iraq. In the agricultural economics literature, Baek and Koo (2007) examined the short- and long-run relationship between the U.S. agricultural trade balance and real income, foreign income, and real exchange rates, and Narayan (2004) analyzed the short- and long-run determinants of sugarcane supply in Fiji.

This study examines two catfish markets: the market for catfish feed and the market for farm-raised catfish. Let feed supply be determined by the feed price ($P_{FD}$), energy prices ($P_E$ and $P_D$) (electricity and diesel fuel, respectively), and feed ingredient prices: corn ($P_C$), soybean meal ($P_S$), cottonseed meal ($P_{CT}$), and distillers dried grains ($P_{DG}$).[1] Let feed demand also be a function of the feed price, and given the derived nature of feed demand, the expected catfish price at the farm level ($P_F^e$), and energy prices. The expected farm price is used because the production period for farm-raised catfish is approximately 2 years and feed purchases in any period are likely a function of expectations. Let the supply of catfish at the farm level be a function of the farm price ($P_F$), energy prices, and the feed price lagged 24 months given the catfish production cycle. Lastly, let catfish demand at the farm level be a function of the farm price, expected catfish prices at the processor level ($P_p^e$), and energy prices.

Given the focus on biofuels, an important issue is the use of ethanol coproducts in catfish feed such as distillers dried grains with solubles (DDGS). Robinson, Li, and Manning (2001) note that DDGS is highly palatable to catfish and contains sufficient levels of protein to be used in place of soybeans and corn at minimal

[1] Catfish feed can also include wheat middling, which can account for approximately 10% of all ingredients. Preliminary analysis indicated that the price of wheat middling need not be in the model given the inclusion of corn and soybean meal prices.

levels (less than 30%). In examining the responsiveness of growth performance and disease resistance to DDGS levels in catfish feed diets, Lim, Yildirim-Aksoy, and Klesius (2009) and Robinson and Li (2008) found that DDGS could be used up to at least 30–40% when diets are supplemented with lysine.

Given market clearing conditions, reduced form feed and farm price equations can be specified as:

$$\begin{aligned}\ln P_{FDt} = {} & \theta_0 + \theta_1 \ln P^e_{Ft} + \theta_2 \ln P_{Ct} \\ & + \theta_3 \ln P_{St} + \theta_4 \ln P_{CTt} + \theta_5 \ln P_{DGt} \\ & + \theta_6 \ln P_{Et} + \theta_7 \ln P_{Dt} + \varepsilon_t\end{aligned} \tag{1}$$

$$\begin{aligned}\ln P_{Ft} = {} & \gamma_0 + \gamma_1 \ln P_{FDt-24} + \gamma_2 \ln P^e_{Pt} \\ & + \gamma_3 \ln P_{Et} + \gamma_4 \ln P_{Dt} + \mu_t.\end{aligned} \tag{2}$$

In a cointegration framework, Equations (1) and (2) are the long-run/levels relationships between feed and farm prices and their regressors (Pesaran, Shin, and Smith, 2001). Given the long-run relationships, the error correction version of the ARDL model can be written as:

$$\begin{aligned}\Delta P_{FDt} = {} & \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta P_{FDt-i} + \sum_{i=0}^{n_1} \varphi_{1i} \Delta P^e_{Ft} \\ & + \sum_{i=0}^{n_2} \varphi_{2i} \Delta P_{Ct-i} + \sum_{i=0}^{n_3} \varphi_{3i} \Delta P_{St-i} \\ & + \sum_{i=0}^{n_4} \varphi_{4i} \Delta P_{CTt-i} + \sum_{i=0}^{n_5} \varphi_{5i} \Delta P_{DGt-i} \\ & + \sum_{i=0}^{n_6} \varphi_{6i} \Delta P_{Et-i} + \sum_{i=0}^{n_7} \varphi_{7i} \Delta P_{Dt-i} \\ & + \lambda_0 \ln P_{FDt-1} + \lambda_1 \ln P^e_{Ft-1} \\ & + \lambda_2 \ln P_{Ct-1} + \lambda_3 \ln P_{St-1} \\ & + \lambda_4 \ln P_{CTt-1} + \lambda_5 \ln P_{DGt-1} \\ & + \lambda_6 \ln P_{Et-1} + \lambda_7 \ln P_{Dt-1} + \nu_t\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta P_{Ft} = {} & \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta P_{Ft-i} + \sum_{i=0}^{q_1} \phi_{1i} \Delta P_{FDt-24-i} \\ & + \sum_{i=0}^{q_2} \phi_{2i} \Delta P^e_{Pt-i} + \sum_{i=0}^{q_3} \phi_{3i} \Delta P_{Et-i} \\ & + \sum_{i=0}^{q_4} \phi_{4i} \Delta P_{Dt-i} + \omega_0 \ln P_{Ft-i} \\ & + \omega_1 \ln P_{FDt-24-1} + \omega_2 \ln P^e_{Pt-1} \\ & + \omega_3 \ln P_{Et-1} + \omega_4 \ln P_{Dt-1} + \upsilon_t.\end{aligned} \tag{4}$$

Note that $\Delta$ is the log-difference operator where for any variable $x$, $\Delta x_t = \ln x_t - \ln x_{t-1}$. $m$, $n$, $p$ and $q$ are the lag orders, and $\nu$ and $\upsilon$ are the errors that are assumed serially uncorrelated. $\varphi$ and $\phi$ represent the short-run dynamics between the dependent and independent variables, and $\lambda$ and $\omega$ give the long-run relationships between the dependent and independent variables.

The first step in this procedure is to estimate Equations (3) and (4) and test for cointegration. No cointegration is implied by the following hypotheses:

$$\begin{aligned}\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = \lambda_7 \\ = 0 \text{ and } \omega_0 = \omega_1 = \omega_2 = \omega_3 = \omega_4 = 0.\end{aligned}$$

The F-statistic for the cointegration restriction does not follow the typical F distribution. Pesaran, Shin, and Smith (2001) give the critical values for this test where they derived upper-bound critical values when all variables are $I(1)$ and lower-bound critical values when all the variables are $I(0)$. Cointegration is confirmed when the F-statistics exceeds the upper-bound critical value at a chosen significance level.

Following Pesaran, Shin, and Smith (2001), the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) are used to determine the optimal lag orders ($m$, $n$, $p$ and $q$). It is particularly important to choose large enough lags to avoid serial correlation but small enough to avoid overparameterization.

If the no cointegration hypothesis is rejected, the long-run relationships can be estimated by Ordinary Least Square (OLS) and the lag residuals can be used as error correction terms when estimating Equations (3) and (4). Let $\hat{\varepsilon}_t$ and $\hat{\mu}_t$ denote the residuals from the long-run feed and farm price equations, respectively. The ARDL equations can be rewritten as:

$$\begin{aligned}\Delta P_{FDt} = {} & \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta P_{FDt-i} + \sum_{i=0}^{n_1} \varphi_{1i} \Delta P^e_{Ft} \\ & + \sum_{i=0}^{n_2} \varphi_{2i} \Delta P_{Ct-i} + \sum_{i=0}^{n_3} \varphi_{3i} \Delta P_{St-i} \\ & + \sum_{i=0}^{n_4} \varphi_{4i} \Delta P_{CTt-i} + \sum_{i=0}^{n_5} \varphi_{5i} \Delta P_{DGt-i} \\ & + \sum_{i=0}^{n_6} \varphi_{6i} \Delta P_{Et-i} + \sum_{i=0}^{n_7} \varphi_{7i} \Delta P_{Dt-i} \\ & + \lambda \hat{\varepsilon}_{t-1} + \nu_t\end{aligned} \tag{5}$$

$$\Delta P_{Ft} = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\Delta P_{Ft-i} + \sum_{i=0}^{q_1} \phi_{1i}\Delta P_{FDt-24-i} + \sum_{i=0}^{q_2} \phi_{2i}\Delta P^e_{Pt-i} + \sum_{i=0}^{q_3} \phi_{3i}\Delta P_{Et-i} + \sum_{i=0}^{q_4} \phi_{4i}\Delta P_{Dt-i} + \omega\hat{\mu}_{t-1} + \upsilon_t \tag{6}$$

where $\lambda$ and $\omega$ measure the speed at which disequilibrium are corrected. Equations (5) and (6) can also be estimated by OLS.

## Data and Descriptive Statistics

Monthly data from January 1995 to December 2008 are used to estimate the long-run feed and farm price equations and the ARDL equations. Data sources include: the National Agricultural Statistics Service (NASS), Bureau of Labor Statistics (BLS), Hanson and Sites (2009), and the Economic Research Service (ERS). Feed prices ($P_{FD}$) were provided by NASS but obtained from Hanson and Sites (2009). Catfish farm prices ($P_F$) and processed catfish prices ($P_P$) were provided by NASS. Corn prices ($P_C$), soybean meal prices ($P_S$), cottonseed meal prices ($P_{CT}$), and DDGS prices ($P_{DG}$) were provide by the ERS feed grains database. We considered two types of energy, diesel fuel and electrical power. The diesel fuel price index ($P_D$) and the electricity price index ($P_E$) were obtained from BLS.

Descriptive statistics are given in Table 2. The average feed price during the data period was \$248.44/ton. Mean catfish prices at the farm and processor levels were \$0.71/lb and \$2.30/lb, respectively. Corn, soybean meal, and cottonseed meal prices averaged \$2.61/bushel, \$202.74/ton, and \$158.47/ton, respectively, and DDGS prices averaged \$103.78/ton. The average value for the diesel price and electricity price indices is 143.62 and 129.74, respectively. Interestingly, the maximum values for all variables occurred in 2008 within a 3-month period. In June 2008, corn prices peaked at \$6.55, and in July 2008, catfish feed prices peaked at \$442.00, soybean and cotton meals prices peaked at \$412.25 and \$333.00, respectively, and the diesel price index reached a maximum of 422.6. In August 2008, farm prices peaked at \$0.84, DDGS prices at \$165.00, and the electricity price index reached a maximum of 177.4.

### *Empirical Results*

OLS is used to estimate Equations (3) and (4) using TSP version 5.0. Lag orders from 0–4 are assumed where the AIC and SBC are used to determine the optimal lag order and the Breusch-Godfrey Lagrange multiplier (LM) statistic is used to determine the presence of serial correlation. Serial correlation invalidates ARDL model estimates and statistical inference. Following Pesaran, Shin, and Smith (2001), autocorrelation up to the fourth order is considered. The AIC, SBC, and LM statistics are reported in Table 3 as well as the F-statistics for the no cointegration hypotheses.

For both feed and farm prices, the AIC indicates that a lag order of 1 is optimal, whereas the SBC indicates that a lag order of 0 is optimal. However, the LM statistics indicate the presence of AR(1), AR(2), AR(3), and AR(4) when a lag

**Table 2.** Model Variables and Descriptive Statistics

| Variable | Unit | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| $P_{FD}$ | \$/ton | 248.44 | 53.48 | 186.00 | 442.00 |
| $P_F$ | \$/lb | 0.71 | 0.08 | 0.53 | 0.84 |
| $P_C$ | \$/bushel | 2.61 | 0.98 | 1.49 | 6.55 |
| $P_S$ | \$/ton | 202.74 | 58.07 | 124.40 | 412.25 |
| $P_{CT}$ | \$/ton | 158.47 | 43.20 | 100.65 | 333.00 |
| $P_{DG}$ | \$/ton | 103.78 | 30.94 | 46.00 | 190.00 |
| $P_P$ | \$/lb | 2.30 | 0.14 | 2.02 | 2.60 |
| $P_E$ | index | 143.62 | 15.13 | 127.90 | 180.20 |
| $P_D$ | index | 129.74 | 85.36 | 38.6 | 422.60 |

**Table 3.** Lag Order Selection and F-statistic for Testing Cointegration

| Lag Order | SBC | AIC | $\chi^2(1)$ | $\chi^2(2)$ | $\chi^2(3)$ | $\chi^2(4)$ | F-statistic |
|---|---|---|---|---|---|---|---|
| | | | | Feed price | | | |
| 0 | –314.58 | –340.40 | **10.80** | **13.95** | **14.44** | **14.80** | 5.71 |
| 1 | –310.51 | –347.03 | 0.00 | 3.82 | 4.51 | 6.00 | 3.67 |
| 2 | –295.07 | –343.76 | 1.39 | 4.40 | 5.59 | 6.00 | 3.59 |
| 3 | –278.18 | –339.05 | 1.44 | 3.49 | 4.49 | 4.90 | 2.65 |
| 4 | –265.56 | –337.08 | 0.73 | 2.94 | 3.88 | 5.46 | 3.11 |
| | | | | Farm price | | | |
| 0 | –357.16 | –373.68 | 3.34 | 5.03 | 4.94 | 4.72 | 7.17 |
| 1 | –352.14 | –374.62 | 0.85 | 0.63 | 0.66 | 0.82 | 5.12 |
| 2 | –340.10 | –370.14 | 0.25 | 1.04 | 1.14 | 1.34 | 3.41 |
| 3 | –330.08 | –367.63 | 0.78 | 1.11 | 3.08 | 4.02 | 2.42 |
| 4 | –320.27 | –365.33 | 2.44 | 4.59 | **10.89** | **10.70** | 2.19 |

Note: $\chi^2$ (*i*) is the Breusch-Godfrey LM statistics for autocorrelation of order *i*. The 5% critical values for AR(1), AR(2), AR(3), and AR(4) are 3.84, 5.99, 7.81, and 9.49, respectively. **Bold** indicates autocorrelation.
The upper-bound critical values (5%) for the cointegration hypotheses are 3.50 and 4.01 for the feed and farm price equations, respectively. These are taken from Pesaran, Shin, and Smith (2001), Table C1(iii), p. 300.
SBC, Schwarz Bayesian Criterion; AIC, Akaike Information Criterion.

order of 0 is assumed for feed prices. Autocorrelation is rejected when lags are added to the feed price model. When the lag order is 0 or 1, the hypothesis of no cointegration is rejected for both feed and farm prices because the F-statistics exceed the 5% upper-bound critical values reported in Pesaran, Shin, and Smith (2001), which are 3.50 and 4.01 for feed and farm prices, respectively.

Because test results indicate that the variables are cointegrated, OLS is used to estimate the long-run relationships, Equations (1) and (2). Results are reported in Table 4. For estimation, we assume that expectations are naive, i.e. $P^e_{Ft} = P_{Ft-1}$ and $P^e_{Pt} = P_{Pt-1}$ which should eliminate any endogeneity problems. The results show that all long-run estimates are significant and consistent with economic theory. Expected farm prices have a positive effect on feed prices (0.061) owning to farm prices being feed demand increasing and hence feed price increasing. Because grain prices are supply decreasing, the responsiveness of feed prices to corn (0.059), soybean meal (0.332), cotton meal (0.087), and DDGS prices (0.106) is positive where the long-run effect of soybean meal prices is approximately three times the effect of DDGS and cotton meal prices and nearly six times the effect of corn prices. Results also show that the long-run responsiveness of feed prices to electricity and diesel prices is 1.089 and –0.073, respectively, suggesting that the decrease in feed supply resulting from rising electricity prices outweighs the decrease in feed demand, and the decrease in feed demand resulting from rising diesel prices outweighs the decrease in feed supply. This is to be expected

**Table 4.** Long-Run Estimates

| Variable | Estimate | |
|---|---|---|
| | Feed Price | |
| *Constant* | –2.278 | (0.465)[a] |
| $\ln P_F^e$ | 0.061 | (0.033)[c] |
| $\ln P_C$ | 0.059 | (0.024)[b] |
| $\ln P_S$ | 0.332 | (0.031)[a] |
| $\ln P_{CT}$ | 0.087 | (0.034)[b] |
| $\ln P_{DG}$ | 0.106 | (0.026)[a] |
| $\ln P_E$ | 1.089 | (0.100)[a] |
| $\ln P_D$ | –0.073 | (0.017)[a] |
| | Farm price | |
| *Constant* | –0.945 | (0.395)[b] |
| $\ln P_P^e$ | 1.538 | (0.066)[a] |
| $\ln P_{FD(-24)}$ | 0.197 | (0.031)[a] |
| $\ln P_E$ | –0.407 | (0.096)[a] |
| $\ln P_D$ | 0.057 | (0.016)[a] |

Standard errors are in parentheses.
[a] Significant at the 0.01 level.
[b] Significant at the 0.05 level.
[c] Significant at the 0.10 level.

because electricity is more important to feed mills than to catfish farmers. However, diesel is used to operate pond aerators, water pumps, generators, and farm vehicles and is more important to farmers.

Long-run farm price estimates show that the expected processor price has the greatest impact on farm prices (1.538), and the long-run effect of feed prices (lagged 24 months) on farm prices is 0.197. The long-run responsiveness of farm prices to the price of electricity is –0.405 indicating that rising electricity prices causes a greater decrease in farm demand than farm supply, suggesting that electricity is relatively more important to processors. The long-run responsiveness of farm prices to the price of diesel fuel is 0.057, indicating that diesel is relatively more important to farmers than processors.

OLS is used to estimate the ARDL Equations (5) and (6). Results and regression diagnostics are reported in Table 5. Given the AIC results in Table 3, the lag order = 1 for both feed and farm prices. LM statistics for AR(1) and AR(4) indicate that autocorrelation is not a problem, White's test for heteroscedasticity indicates that the errors are homoscedastic, and Ramsey's RESET tests indicate that the ARDL equations are correctly specified. The Jarque-Bera statistics indicate that normality could not be rejected for feed prices but rejected for farm prices. However, as noted by Greene (2008, p. 18), normality is not necessary for validity of the classical linear regression model. Given the timespan of the data, there is the possibility of structural change, particular in more recent years when grain prices reached record peaks. The CUSUM and

**Table 5.** ARDL/Short-Run Estimates with Error Correction

| | Feed Price | | | Farm Price | |
|---|---|---|---|---|---|
| Variable | Estimate | | Variable | Estimate | |
| $\Delta P_{FDt\text{-}1}$ | –0.1036 | (0.0743) | $\Delta P_{Ft\text{-}1}$ | 0.7836 | (0.0963)[a] |
| $\Delta P^e_{Ft}$ | –0.1138 | (0.1035) | $\Delta P^e_{Pt}$ | 0.1173 | (0.1388) |
| $\Delta P^e_{Ft\text{-}1}$ | 0.2308 | (0.1018)[b] | $\Delta P^e_{Pt\text{-}1}$ | –0.2750 | (0.1102)[b] |
| $\Delta P_{Ct}$ | 0.0321 | (0.0304) | $\Delta P_{FDt\text{-}24}$ | 0.0225 | (0.0482) |
| $\Delta P_{Ct\text{-}1}$ | 0.0841 | (0.0317)[a] | $\Delta P_{FDt\text{-}24\text{-}1}$ | 0.0368 | (0.0472) |
| $\Delta P_{St}$ | 0.1578 | (0.0316)[a] | $\Delta P_{Et}$ | 0.0685 | (0.2890) |
| $\Delta P_{St\text{-}1}$ | 0.0028 | (0.0386) | $\Delta P_{Et\text{-}1}$ | –0.2006 | (0.2813) |
| $\Delta P_{CTt}$ | 0.0977 | (0.0265)[a] | $\Delta P_{Dt}$ | –0.0018 | (0.0190) |
| $\Delta P_{CTt\text{-}1}$ | 0.0914 | (0.0278)[a] | $\Delta P_{Dt\text{-}1}$ | 0.0423 | (0.0202)[b] |
| $\Delta P_{DGt}$ | 0.0335 | (0.0201)[c] | | | |
| $\Delta P_{DGt\text{-}1}$ | –0.0214 | (0.0201) | | | |
| $\Delta P_{Et}$ | 0.1897 | (0.3621) | | | |
| $\Delta P_{Et\text{-}1}$ | 0.2375 | (0.3579) | | | |
| $\Delta P_{Dt}$ | –0.0116 | (0.0236) | | | |
| $\Delta P_{Dt\text{-}1}$ | 0.0074 | (0.0243) | | | |
| $EC_{t\text{-}1}$ | –0.2777 | (0.0584)[a] | $EC_{t\text{-}1}$ | –0.1340 | (0.0503)[a] |
| *Constant* | 0.0012 | (0.0022) | *Constant* | –0.0001 | (0.0018) |
| $R^2$ = 0.646; SBC = –324.26; AIC = –350.13 | | | $R^2$ = 0.443; SBC = –359.37; AIC = –369.88 | | |
| Breusch–Godfrey LM AR(1) = 0.414[.520] | | | Breusch–Godfrey LM AR(1) = 2.350[.125] | | |
| Breusch–Godfrey LM AR(4) = 1.680[.794] | | | Breusch–Godfrey LM AR(4) = 4.467[.347] | | |
| White heteroscedasticity = 150.004[.531] | | | White heteroscedasticity = 34.755[.121] | | |
| Jarque–Bera (normality) = 0.889[.641] | | | Jarque–Bera test (normality) = 16.678[.000]* | | |
| Ramsey's RESET (specification) = 2.171[.143] | | | Ramsey's RESET (specification) = 3.296[.072] | | |

EC is the error correction term. Standard errors are in parentheses.
[a] Significant at the 0.01 level.
[b] Significant at the 0.05 level.
[c] Significant at the 0.10 level.
ARDL, autoregressive distributed lag; SBC, Schwarz Bayesian Criterion; AIC, Akaike Information Criterion; LM, Lagrange multiplier.

CUSUMQ tests are used to test for structural change and to determine if the estimated parameters in Equations (5) and (6) are stable. Test results indicate that the parameters are stable over the data period (see Figures 2 and 3).

Of particular importance is the speed at which the catfish feed and farm markets adjust to long-run equilibrium. The error correction (EC) estimate is –0.2777 for catfish feed prices and –0.1340 for farm prices. Both are significant at the 0.01 level and the negative signs ensure that long-run equilibria are achieved. EC estimates indicate that feed prices adjust approximately 27.77% to the long-run equilibrium in 1 month and that it takes less than 4 months ($1 \div 0.2777 = 3.601$) to correct long-run disequilibria. Farm prices adjust approximately 13.4% to the long-run equilibrium in 1 month and it takes approximately 7½ months ($1 \div 0.134 = 7.463$) to correct long-run disequilibria.

Because the biological lag in catfish production is much longer than the lag in feed production, we would expect that it takes longer for catfish farmers to respond to exogenous shocks. Additionally, adjustment costs in catfish production may be significantly higher when compared with feed production. For instance, it is plausible that a significant number of feed mills could respond immediately to changes in grain prices. In contrast, rigidities in farm supply can be quite substantial because the initial decision to stock ponds could limit a producer's responsiveness for approximately 2 years.

In comparing the ARDL feed and farm price results (short-run estimates), the feed price equation is a relatively better fit when compare with the farm price. Furthermore, more variables are significant in the feed price equation in which there is a significant positive relationship between feed prices and expected farm prices (lagged 1 month) (0.2308), corn prices (lagged 1 month) (0.0841), soybean meal prices (0.1578), and DDGS prices (0.0335). There is both an immediate and lag effect for cottonseed meal prices (0.0977 and 0.0914, respectively). Similar to the long-run estimates, soybean meal prices have the greatest effect on feed prices in the short run; however, the relative magnitude between estimates is not as great. The relatively large estimates for soybean meal prices is the result of soybean meal being the predominant protein source used in catfish feeds where levels up to 50% have been used without detrimental effects on growth (Robinson, Li, and Manning, 2001).

Results show that the short-run responsiveness of farm prices is mostly explained by farm prices in the previous period (0.7836), and interestingly, the effect of processor price expectations (lagged 1 month) on farm prices is negative (–0.2750)

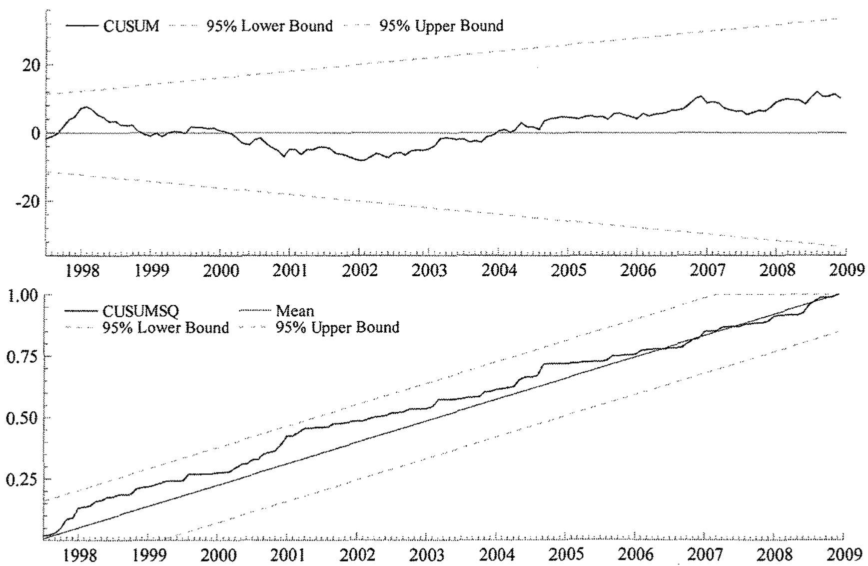


**Figure 2.** CUSUM and CUSUMQ Test for Parameter Stability: Catfish Feed Price

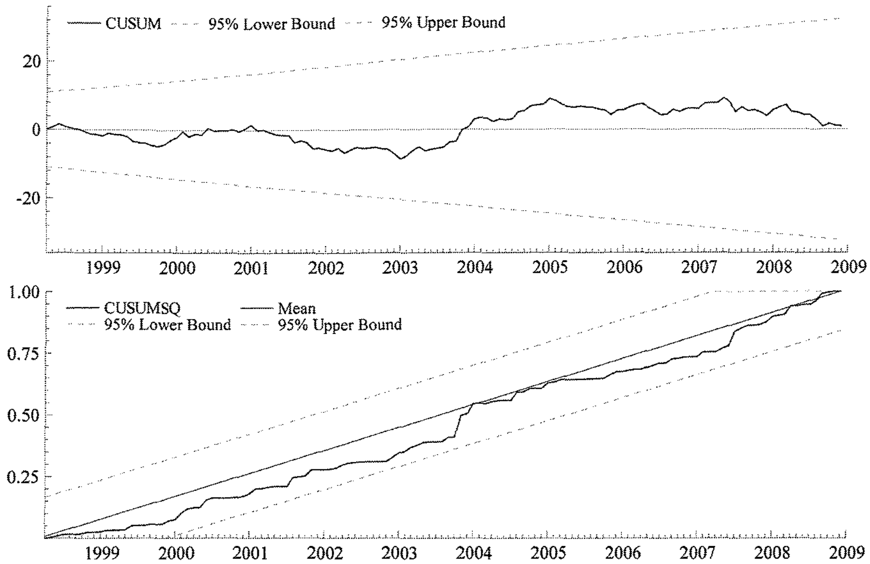


**Figure 3.** CUSUM and CUSUMQ Test for Parameter Stability: Catfish Farm Price

suggesting that processor price expectations are demand decreasing in the short run. Put differently, processors may choose to delay farm purchases until prices actually rise. For fresh processor sales, this is plausible because fresh catfish is highly perishable and farm quantities are somewhat inelastic in the short run. Because frozen catfish is storable, this is less plausible but could still be likely. Lastly, there is a significant positive relationship between farm and diesel prices (0.0423) in the short run.

*Long-Run Effects of Ethanol Production*

Using the estimated relationship between grain prices and ethanol production reported in previous studies, catfish feed and farm price elasticities with respect to ethanol production can be calculated using model estimates. According to the U.S. Department of Energy (2005), 54% of the increase in corn prices and 49% of the increase in soybean prices from June 2007 to July 2008 were the result of the growth in ethanol production.[2] Ethanol production increased from 549.4 to 799.8 million gallons during this period, which is a 46% increase (Energy Information Administration, 2009). Also during this period, corn prices increased by 62.2% from \$3.68 to \$5.97, and soybean meal prices increased by 79.5% from \$229.70 to \$412.25 (U.S. Department of Agriculture, Economic Research Service, 2009). Using these changes, the corn price elasticity with respect to ethanol production is 0.73, and the soybean meal price elasticity with respect to ethanol production is 0.85.[3] Recall that the long-run responsiveness of feed prices to corn and soybean meal prices is 0.059 and 0.332, respectively, and the long-run responsiveness of farm prices to feed prices is 0.197. Using these estimates, the long-run responsiveness of catfish feed prices to ethanol production is 0.325 ($0.059 \times 0.73 + 0.332 \times 0.85$) and farm prices to ethanol production is 0.064 ($0.197 \times 0.325$).

Although both farm and feed prices increase when ethanol production expands, farmers still lose profits given the relatively smaller increase in farm prices when compared with feed prices. According to Dorman (2009), growing a fingerling to market size (1.5 pounds) requires 3.73 pounds of feed, which is an input–output ratio of about 2.5. Using this ratio and average feed and

[2] U.S. Department of Energy results are reported in Muhammad and Kebede (2009).

[3] $\%\Delta P_C \div \%\Delta ethanol = [0.622 \times 0.54]/0.46 = 0.73$; $\%\Delta P_S \div \%\Delta ethanol = [0.795 \times 0.49]/0.46 = 0.85$.

farm prices, it can easily be shown that for every percentage increase in feed prices, farm prices must increase by 0.4% for profits to be the same. Note that the long-run farm price elasticity with respect to feed prices (0.197) is significantly smaller than 0.4 suggesting that catfish farmers will lose profits when feed prices increase, ceteris paribus.

## Summary and Conclusion

In this article, we examined the dynamic relationship between catfish feed and farm prices and their regressors. Given the relationship between ethanol production and grain prices, the impact of U.S. ethanol production on the catfish feed and farm sector was assessed. The ARDL model and bounds testing procedure were used in estimation. Results indicated that there was a significant long-run relationship among catfish feed prices, grain prices, and energy prices. Additionally, there was a significant long-run relationship among farm prices, feed prices, processor prices, and energy prices.

Although both catfish feed and farm prices increase with U.S. ethanol production, the relatively small responsiveness of farm prices when compared with feed prices suggests that catfish farmers are consequently worse off. The results of this study show that farm prices do not fully reflect changes in feed costs, and an increase in feed cost would likely hurt catfish farmers. This indicates that farmers are not able to pass on increased production cost to processors.

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