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Price Volatility Spillover in Agricultural Markets: An Examination of U.S. Catfish Markets

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Price volatility spillovers in the U.S. catfish supply chain are analyzed based on monthly price data from 1980 through 2000 for catfish feed, its ingredients, and farm- and wholesale-level catfish. The exponential generalized autoregressive conditional heteroskedasticity (EGARCH) model was used to test univariate volatility spillovers for prices in the supply chain. Strong price volatility spillover from feeding material (corn, soybeans, menhaden) to catfish feed and farm- and wholesale-level catfish prices was detected.

Key words: catfish, EGARCH, vertical market chains, volatility spillover

Introduction

Price volatility has long been recognized by economists as an important economic phenomenon (Engle). It complicates price discovery and represents risk to economic agents. Volatility became a major topic of discussion during the debate for the 1996 Federal Agriculture Improvement and Reform (FAIR) Act (Ray et al.). The initial perception was that decoupling of farm program payments would lead to increased price volatility, a prediction which has proven true for some commodities and false for others (Yang, Haigh, and Leatham). Ample evidence suggests volatility is important in agricultural commodities (Hudson and Coble; Kinnucan 1986; Goodwin and Schnepf). But does volatility in one market necessarily lead to volatility in other markets? The answer to this question has important policy ramifications. If volatility does spill over through market channels, policy changes in primary input markets that alter price volatility will have impacts on price volatility through vertical market chains. These spillovers will then need to be considered in public policy decisions.

Volatility transmission (also called spillovers) in financial markets has been well documented (Aspergis and Rezitis; Reyes; Hong; Kanas and Kourteas; Kim and Rui; Tse; Gallagher and Twomey; Byars and Peel), but has received much less attention in agriculture. One might expect that arbitrage of stock prices across markets (e.g., New York and Tokyo) should result in volatility transmission between markets. Likewise, arbitrage of a physical commodity such as beef between auction markets may lead to volatility transmission as well (Natcher and Weaver).

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In this study, the transmission of volatility is examined within a vertical supply chain, which has received little attention in the literature (Haigh and Bryant; Haigh and Holt). Additionally, asymmetric transmission of volatilities has been analyzed in financial assets (Aspergis and Rezitis; Reyes), but has not been scrutinized in agricultural markets. The question to be answered in this study is the following: Does price volatility in input markets transmit itself through higher market levels, and vice versa? Farm product prices depend on current and expected levels of demand- and supply-shifting variables. Competitive price transmission processes suggest consumer demand determines retail price, assuming a given supply, with lower market-level prices being determined by subtraction of processing, transportation, and other costs (at least in the short run). Given the vertical linkages and transmission of prices between market levels, a reasonable hypothesis is that volatility would be transmitted between market levels as well (Haigh and Bryant).

The specific objective of this study is to examine the extent to which volatility in primary input markets—soybeans and corn—spills over into feed and fed animal—catfish—markets. First, volatility in each market is examined individually to establish baseline price behavior. Then, contemporaneous volatilities are used as exogenous variables to examine volatility spillover.[1] Catfish was chosen as the example because catfish markets are small relative to corn and soybean markets, so that a simplifying assumption of unidirectional spillover is warranted. Because there is no futures market for catfish, a finding of volatility spillover between corn and soybean markets would open the door for potential cross-hedge relationships not previously employed in these markets.[2]

A critical area in the present study is asymmetric volatility transmission. Studies addressing whether wholesalers of agricultural commodities have the power to asymmetrically influence prices on farm or retail levels have been conducted for fresh vegetables (Ward), dairy products (Kinnucan 1987), citrus (Pick, Karrenbrock, and Carman), and cattle (Bailey and Brorsen). Miller and Hayenga tested whether there was asymmetric price transmission in the U.S. pork market and found changes in wholesale prices are asymmetrically transmitted to retail prices. Goodwin and Holt examined price interrelationships and transmission among farm, wholesale, and retail markets for the beef sector. These authors concluded that transmission of shocks was largely unidirectional, with information flowing up the market channel from farm to wholesale to retail markets. In their study of the U.S. broiler industry, Bernard and Willet found that concentration and power of integrators have allowed the wholesale price to become the center, causal price in the market, and asymmetric price transmission is limited.

Given the overall importance of asymmetric price transmission, investigation of asymmetric price volatility transmission is warranted as well. A secondary objective of this analysis is to examine potential asymmetries in volatility transmission between market levels. As with price levels, asymmetric volatility transmission is an indicator of potential market power.

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[1] A number of factors may contribute to price volatility, including supply and demand factors, other meats, etc. For simplicity, only input price volatility is considered here.

[2] Vukina and Anderson have examined cross-hedging fish meal with soybean meal futures. However, no one has examined cross-hedging fish prices with their constituent input market prices.

Catfish Industry and Supply Chain

Farm-raised catfish is a grain-fed food fish raised predominantly in the southern United States. It is the fifth most popular fish in terms of *per capita* consumption in the United States after tuna, pollock, salmon, and cod. Production of farm-raised catfish was approximately 600 million pounds in 1999. The farm-raised catfish industry is centered in Alabama, Arkansas, Louisiana, and Mississippi, with these four states accounting for 95% of all catfish production. Sales of farm-raised catfish total approximately $500 million annually, but the total impact on the economies of the four major catfish-producing states exceeds $4 billion annually [U.S. Department of Agriculture, National Agricultural Statistics Service (USDA/NASS)].

The highest variable cost input for producing catfish is feed; therefore, changes in feed costs cause dramatic changes in the cost of producing catfish. For example, increasing the feed price from $231 to $281 per ton (22%) increases the total cost of production from $0.581 to $0.632 per pound (9%) of catfish produced on the farm (Posadas and Dillard). An average catfish feed formulation can be 75% corn gluten and soybean meal (table 1). The large share of feed in total production costs suggests the feed-related forces driving expansion and contraction of catfish production resemble those faced in the hog and poultry industries. From 1993 to 1999, nominal prices of corn, soybean, and menhaden have changed substantially. Corn averaged $2.22/bushel in 1993, rose to over $3.50/bushel in 1996, and then declined to $2.21/bushel in 1998. Price volatility of corn has increased since the United States' entrance into international markets in the early 1970s (Khan and Helmers). The price of menhaden averaged $332/ton in 1994, rose to $518/ton in 1999, and then declined rapidly to $344/ton in 1999.

Generally, feed meal processors purchase corn, soybean, and menhaden from open markets acting as price takers due to the small size of their transactions relative to total volume sold in the primary input markets. Other than the fish themselves, feeds are the primary input into the catfish production process, and farmers purchase their feeds from these feed processors. Catfish producers then sell finished fish to processors who prepare them for retail markets. Because catfish processing is a concentrated industry with the four-firm concentration ratio at about 65% in 1999 (Hudson and Hanson), processors may have enough influence to affect both wholesale- and farm-level catfish prices. At present, retail price data are not available. Thus, wholesale prices are the highest market level examined in this analysis.

Spillover of price volatility is an important problem to the catfish industry. Most significantly, because the industry is not highly integrated in terms of production and marketing, input and output price volatility become a major source of uncertainty for catfish producers and processors, and the industry is highly vulnerable to input price volatilities. Results of this study, therefore, could have implications for fish producers, feed manufacturers, and processors, because indications of volatility spillover could introduce cross-hedge relationships for producers and can provide predictions about price volatility in catfish markets as a result of changes in volatility in related markets.

Data and Methods

Time-series evidence concerning price transmission and price volatility in the catfish industry is explored using monthly cash price data at the farm and wholesale levels.

Table 1. Major Ingredients and Cost (as-fed basis) of Experimental Diets Fed to Catfish

Ingredients	Cost ($ per ton)	32% Protein Feed	
		% Composition[a]	$/Ton of Feed
Ground corn	91.51	32.2	29.47
Soybean meal (dehulled)	235.96	47.3	111.61
Menhaden fish meal	476.81	8.0	38.14
Wheat middlings	100.00	9.6	9.60

Source: Hatch et al.
[a] Percent composition is on a weight basis.

Soybean prices are #1 yellow cash prices in central Illinois, and corn prices are #2 yellow Chicago cash prices. Farm- and wholesale-level catfish prices were obtained from USDA/NASS and are national averages. Corn and soybean price data were obtained from Bridge Data, Inc., and menhaden price data were obtained from Omega Protein, Inc., and are national averages as well. All price data were monthly for the time period January 1980 through December 2000.

Descriptive statistics are reported in table 2 for monthly percentage changes in the price series under consideration. The skewness and kurtosis measures indicate corn and feed prices are negatively skewed and leptokurtic, and farm- and wholesale-level catfish, soybean, and menhaden prices are all positively skewed and leptokurtic relative to the normal distribution. We reject normality in all cases based on the Jarque-Bera statistic.

It is necessary to determine the time-series properties (or the order of integration) of each variable to avoid the problem of nonstationarity of the data by testing for a stochastic trend. The augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) nonparametric tests were employed as univariate tests of the null hypothesis of a unit root in the data. The null hypothesis of a unit root in the series under consideration cannot be rejected at the 5% level of significance for all commodities. To examine the data for presence of a second unit root, the ADF and PP tests were applied to the first differences of the series. The presence of a second unit root is rejected at the 5% level. Therefore, the first differences of all series under consideration are stationary, confirming the series are likely I(1) in the logarithms of the levels.

Seasonality in Volatility

It is hypothesized that patterns of seasonality may be present in volatility patterns for each series under consideration. Previous research has confirmed the presence of strong seasonality in price volatility (Goodwin and Schnepf). In particular, volatility appears to peak in the summer months for most agricultural commodities.[3] Following Goodwin and Schnepf, a deterministic seasonal component is incorporated into models of variability by adding a sum of trigonometric functions corresponding to the month of the year. Defining d_t to be the month of the year corresponding to observation t, the seasonal component can be written as:

[3] Although catfish is produced year round, there are definite seasonal components in price (Hudson and Hanson); thus, seasonality in volatility is also expected.

Table 2. Summary Statistics of Percentage Changes in Monthly Prices, 1980–2000

	Statistics				
Price Series	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera Test[a]
Catfish farm level	-0.0028	0.028	0.504	3.984	14.64 (0.001)
Catfish wholesale level	0.0007	0.019	0.823	4.062	28.29 (0.000)
Corn	-0.0007	0.069	-0.567	6.889	121.08 (0.000)
Soybeans	-0.0004	0.047	0.309	6.342	85.23 (0.000)
Menhaden	0.0012	0.053	0.393	8.155	200.00 (0.000)
Feed (32% protein)	-0.0003	0.033	-0.487	6.512	97.96 (0.000)

[a] Numbers in parentheses are p-values for Jarque-Bera statistics.

$$s_i = \sum_{i=1}^{k}\left[\phi_i \cos\left(\frac{2\pi i d_t}{12}\right) + \varphi_i \sin\left(\frac{2\pi i d_t}{12}\right)\right].$$

This specification provides a seasonal function with a period of one year and can be interpreted as providing a kth-order Fourier approximation to the unknown seasonal function. Following Goodwin and Schnepf, $k = 3$ is used in representing the seasonal components.

Univariate EGARCH Model and Volatility Spillover

The exponential generalized autoregressive conditional heteroskedasticity (EGARCH) model developed by Nelson is used in order to capture the asymmetric impact of shocks on volatilities and to avoid imposing nonnegativity restrictions on the values of the GARCH parameters (Bollerslev) to be estimated. Specifically, percentage changes in prices are modeled as follows:

(1) $$R_t = \alpha_0 + \sum_{i=1}^{r} \alpha_i R_{t-i} + \varepsilon_t,$$

where

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, \sigma_t^2)$$

and

(2) $$\log(\sigma_t^2) = \exp\left(a_0 + \sum_{i=1}^{q} a_i g(z_{t-i}) + \sum_{i=1}^{p} b_i \log(\sigma_{t-1}^2)\right),$$

(3) $$g(z_t) = \theta z_t + \left[\,|z_t| - E|z_t|\,\right].$$

From the above equations, R_t denotes the percentage change in prices, ε_t is the stochastic error, Ω_{t-1} is the information set at time $t-1$, σ_t^2 is the conditional (time-varying) variance, and z_t is the standardized residual (ε_t/σ_t). Conditional on Ω_{t-1}, ε_t is assumed to be normally distributed with a zero mean and variance σ_t^2.

Equation (1), the conditional mean equation, is specified as an autoregressive process of order r [AR(r)]. The autocorrelation and partial autocorrelation functions are considered and residuals from the mean equations are tested for whiteness using the Ljung-Box statistics to determine the lag length, r, for each return series. Two lags were found to be optimal for each return series to yield uncorrelated residuals for the time period considered (January 1980 through December 2000).

Equation (2), the conditional variance equation, reflects the EGARCH (p, q) representation. According to EGARCH, the variance is conditional on its own past values as well as a function of z_t, or the standardized residuals (ε_t/σ_t). We are also typically concerned about potential persistence in volatility, which is an indicator of market efficiency.[4] The persistence of volatility implied by equation (2) is measured by $\Sigma_{i=1}^{p} b_i$. If the unconditional variance is finite, $\Sigma_{i=1}^{p} b_i < 1$ in absolute value. The smaller the absolute value of this sum, the less persistent volatility is after a shock.

In equation (3), the second term, $[|z_t| - E|z_t|]$, captures the ARCH effect, which is similar to the concept behind the GARCH specification. The parameter θ allows for this ARCH effect to be asymmetric.[5] A statistically significant θ indicates an asymmetric effect exists. The response to rising prices (positive shock) at any production or marketing stage can differ from the response to price declines (negative shock). For instance, the wholesale market structure could be sufficiently oligopolistic so that price stickiness occurs, producing an asymmetric response to farm-level price changes.[6] Because catfish processing is a concentrated industry, some degree of asymmetric price response might be expected in catfish markets. Lag truncation lengths, p and q, are determined using likelihood-ratio (LR) tests of alternative specifications. Based on these tests, EGARCH (1, 1) models were determined to be optimal.

In this analysis, the univariate EGARCH model is used to test for volatility spillover from the feeding material supply chain to catfish prices and middle stages, namely: (*a*) from corn, soybean, feedstuff, menhaden, and farm-level catfish prices to wholesale-level catfish prices; (*b*) from corn, soybean, feed stuff, menhaden, and wholesale-level catfish prices to farm-level catfish prices; and (*c*) from corn, soybean, and menhaden prices to feed stuff prices.[7] We assume unidirectional volatility spillover to be relevant because catfish production is not large enough to have a substantial impact on corn and soybean prices.

The approach used by Hamao, Masulis, and Ng; Kanas; and Theodossiou and Lee is followed to test for spillover from any supply chain material to catfish prices. According

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[4] That is, if markets are efficient, they should immediately dissipate any shocks with no persistence in volatility.

[5] If $\theta = 1$, a positive shock has the same effect as a negative shock of the same magnitude. If $-1 < \theta < 0$, a negative shock increases volatility more than a positive shock, and thus θ measures the asymmetric effect of shocks on volatility. If $\theta < -1$, a negative (positive) shock actually increases (reduces) volatility.

[6] Of course, other reasons than market structure being oligopolistic might create price stickiness. However, market structure is a primary cause and serves as an illustration of why asymmetric price responses might arise.

[7] Ideally, one would want to estimate the conditional variance equations for each variable in a system of equations. The process used here may be inefficient because each equation is estimated independently with predicted values for each conditional variance entering all other equations as an exogenous variable, thus necessitating the estimation of multiple equations subject to error. Limited degrees of freedom prevented the estimation of a system of equations. However, simultaneous models with only farm-level/wholesale-level prices and feed stuff prices revealed similar results found in the univariate models of all constituent inputs presented here. Nevertheless, the reader should note that use of simultaneous equations is preferred to prevent loss of estimation efficiency.

to these authors, the most recent squared residuals from the mean-conditional variance formulation of the supply chain materials are introduced as an exogenous variable in the conditional variance equation for catfish prices. To illustrate, consider case (a) above. To test for spillover from corn, soybean, feed stuff, menhaden, and farm-level catfish prices to wholesale-level catfish prices, the squared residual series for corn, soybean, feed stuff, menhaden, and farm-level catfish are introduced as exogenous variables in the conditional variance equation of wholesale-level catfish prices. Thus, the conditional variance equation for wholesale-level catfish prices becomes:

$$\begin{aligned}\log(\sigma^2_{whlcat,t}) = \exp\big[a_0 &+ a_1(z_{whlcat,t-1}) + b_1\log(\sigma^2_{whlcat,t-1}) + c_1\log(U_{corn,t}) \\ &+ c_2\log(U_{soy,t}) + c_3\log(U_{feed,t}) + c_4\log(U_{menh,t}) \\ &+ c_5\log(U_{farmcat,t})\big],\end{aligned}$$

where $U_{corn,t}$, $U_{soy,t}$, $U_{feed,t}$, $U_{menh,t}$, and $U_{farmcat,t}$ are the contemporaneous squared residuals from the AR(2)-EGARCH(1, 1) models for corn, soybean, feed stuff, menhaden, and farm-level catfish prices, respectively, and $z_{whlcat,t-1}$ represents the lagged standardized residuals for wholesale catfish prices. Existence of volatility spillover is indicated by the statistical significance of c_1 through c_5. Statistical inference regarding these parameters (the c notations) is based on robust standard errors derived by Bollerslev and Wooldridge to allow for possible violations of the assumption of normality for the conditional errors.[8]

Given a sample of T observations and conditional normality for the price returns in each equation, the log-likelihood function for the univariate EGARCH is written as:

$$L(\Theta) = \left(\frac{-T}{2}\right)\log(2\pi) - 0.5\sum_{i=1}^{T}\log(\sigma_t^2),$$

where Θ is the parameter vector (a_0, a_1, α_0, α_1, α_2, b_1, c_1, c_2, c_3, c_4, c_5, θ) to be estimated. The Berndt, Hall, Hall, and Hausman algorithm is used to maximize $L(\Theta)$ in TSP version 4.

Results

All models were determined to be best fit by EGARCH (1, 1) except for menhaden, which was best fit by EGARCH (2, 1). The estimation results for the EGARCH models are presented in table 3. The degree of volatility persistence (as measured by b_1) is statistically significant and close to 1 (or −1) except for menhaden. This result suggests that once a shock has occurred, volatility tends to persist for long periods in all markets except menhaden, where the length of persistence appears to be shorter.

The asymmetric effect parameter, θ, is only significant for catfish farm-level prices. The sign on this coefficient is positive, suggesting a positive shock does not have the same effect as a negative shock of the same magnitude. More generally, a positive shock increases volatility more than a negative shock. Statistical significance of the asymmetric parameter only at the farm level implies catfish farmers asymmetrically influence catfish prices, despite the fact it is catfish processing that is heavily concentrated. This

[8] Conventional standard errors tend to underestimate the true standard errors, especially for the parameters in the conditional variance equations (Susmel and Engel).

Table 3. EGARCH Model Estimation Results, Monthly Data, 1980–2000

Parameters[a]	Farm	Wholesale	Corn	Soybeans	Menhaden	Feed Stuff
α_1	0.51**	0.21**	0.46**	0.24**	0.37**	-0.02*
	(7.05)	(2.56)	(5.04)	(2.79)	(9.67)	(-1.79)
α_2	-0.12	0.11	-0.19*	-0.06	-0.08**	0.09
	(-1.77)	(1.53)	(-2.32)	(-1.03)	(-6.39)	(1.12)
a_0	-12.66**	-0.06	-11.31**	-0.59**	-3.77**	-1.03
	(-20.79)	(-0.28)	(-74.21)	(-2.63)	(-2.96)	(-1.00)
a_1	0.36**	-0.09	0.24**	-0.15*	0.32**	0.24**
	(3.16)	(-0.72)	(3.14)	(-1.91)	(2.88)	(2.15)
a_2	—	—	—	—	-0.41**	—
					(-3.19)	
b_1	-0.64**	0.98**	-0.94**	0.88**	0.38*	0.87**
	(-8.81)	(56.02)	(-32.86)	(21.26)	(1.83)	(6.09)
θ	0.46**	-0.07	-0.04	0.07	0.17	0.06
	(4.55)	(-0.61)	(-0.96)	(0.66)	(1.24)	(0.77)
Log Likelihood	421.48	474.20	255.69	299.83	296.99	363.30
Diagnostics on Standardized and Squared Standardized Residuals:						
Ljung-Box [16]	12.67	16.40	10.62	8.58	25.16	11.56
	(0.696)	(0.310)	(0.864)	(0.940)	(0.053)	(0.766)
Ljung-Box^2 [16]	18.96	20.61	10.53	16.96	7.61	10.17
	(0.270)	(0.167)	(0.921)	(0.520)	(0.960)	(0.855)
Jarque-Bera	16.94	4.71	70.69	30.59	80.67	53.16
	(0.001)	(0.095)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Single and double asterisks (*) denote statistical significance at the 0.05 and 0.01 levels, respectively. In upper portion of table, values in parentheses below parameter estimates are robust t-statistics; in bottom portion of table, numbers in parentheses beneath diagnostic statistics are p-values.

[a] The parameters α_1 and α_2 are the coefficients on the first- and second-order autoregressive processes specified for the mean equations, b_1 is the measure of volatility persistence, and a_1 and a_2 are the measures of the autoregressive conditional heteroskedasticity.

result is not necessarily unexpected, however, because catfish processing is heavily dominated by cooperatively owned processing firms, which would tend to mitigate the effects of concentration at the processing level and increase the influence farmers have over farm-level prices. The Ljung-Box statistics (table 3) on standardized and squared residuals indicate the EGARCH model captures all linear and nonlinear dependencies in the percentage change for all price series. Finally, the Jarque-Bera normality test results show that standardized residuals for all price series except wholesale catfish exhibit strong deviations from normality, thus justifying the use of the robust t-statistical inferences.

Results of seasonality tests are presented in table 4. Trigonometric seasonality components are only statistically significant in a few cases, suggesting some seasonal component to volatility, but not strong seasonality. The pattern of seasonality is shown in figures 1 and 2. Volatility peaks in the first quarter of the year due to rapid changes in demand during Lent season. Another peak occurs in the early summer months, which is associated with uncertainty about supply during the growing season and a relative shortage of fish based on demand during these months. There is another peak during the fall, which is associated with the harvest. Volatility patterns are more pronounced for the farm-level prices (figure 1) as compared to wholesale-level prices (figure 2).

Table 4. Maximum-Likelihood Estimation Results for Monthly Seasonality in Volatility of Prices, 1980–2000

Parameters	Farm	Wholesale	Corn	Soybeans	Menhaden	Feed Stuff
Intercept (Mean)	-0.003*	-0.004*	0.010*	0.003	0.002	-0.003*
	(-2.17)	(-3.27)	(3.02)	(1.12)	(0.64)	(-1.95)
AR(1)[a]	0.38*	0.16*	0.46*	0.29*	0.43*	0.11
	(4.54)	(2.32)	(5.63)	(4.39)	(6.15)	(1.21)
AR(2)[a]	0.01	0.09	-0.11*	-0.03	-0.09*	-0.01
	(0.24)	(1.30)	(-2.02)	(-0.57)	(-1.94)	(-0.08)
Intercept (Variance)	-8.03*	-8.39*	-6.09*	-6.46*	-6.55*	-7.23*
	(-56.64)	(-45.04)	(-30.48)	(-31.07)	(-34.89)	(-36.14)
SIN1	-0.08	-0.10	0.92*	0.36*	0.80*	0.33
	(-0.42)	(-0.64)	(4.41)	(2.13)	(3.13)	(1.11)
SIN2	-0.75*	-0.15	0.22	-0.06	0.47*	0.15
	(-5.04)	(-0.97)	(1.51)	(-0.30)	(2.54)	(1.07)
SIN3	-0.44*	-0.04	0.08	-0.02	0.05	0.32
	(-2.72)	(-0.22)	(0.43)	(-0.07)	(0.19)	(1.18)
COS1	0.15	0.87*	-1.19*	-0.78*	0.43*	-0.22
	(0.61)	(4.51)	(-5.97)	(-3.91)	(2.27)	(-1.10)
COS2	-0.07	0.46*	-0.12	-0.14	0.02	0.23
	(-0.28)	(2.85)	(-0.51)	(-0.95)	(0.07)	(0.74)
COS3	-0.05	-0.27*	0.32	0.46*	0.33	0.56*
	(-0.27)	(-1.98)	(1.57)	(3.58)	(2.45)	(3.22)
Log Likelihood	425.31	479.03	279.53	316.07	304.79	368.98

Notes: An asterisk (*) denotes statistical significance at the 0.01 level. Values in parentheses are robust t-statistics.
[a] AR(1) and AR(2) are the first and second lags of the price series.

The apparent lack of strength in seasonality may be attributed to a changing seasonal pattern in catfish production. Specifically, in the early part of the sample, this observed seasonal pattern in figures 1 and 2 is generally believed to be strong. However, as technology and production practices have changed in recent years, harvest of fish is virtually continuous, leading to a dampening of the seasonal patterns observed in earlier years. Thus, as time progresses, the seasonal patterns are expected to become less pronounced.

The results of the univariate EGARCH model testing volatility spillover are reported in table 5. There is a significant volatility spillover from feed stuff, menhaden, and wholesale catfish prices to farm-level catfish prices. The magnitude of the spillover coefficient varies from 0.22 for feed stuff, to -0.24 for menhaden, to 0.14 for wholesale catfish prices. Corn price volatility also spills over into catfish prices, suggesting it is not only the immediately adjacent market levels that affect price volatility, but primary input markets as well. This result could have important implications for catfish producers because there are no futures markets for catfish, or catfish feed (including menhaden). However, given that corn price volatility does significantly influence catfish price volatility, a cross-hedge with corn may be viable.

For wholesale catfish price volatility, the only statistically significant spillover effect observed is from farm-level catfish prices to wholesale prices. This finding supports Ward and Stevens' hypothesis that price linkages within the vertical supply chain weaken as the product is transformed. For feed stuff prices, there is significant volatility

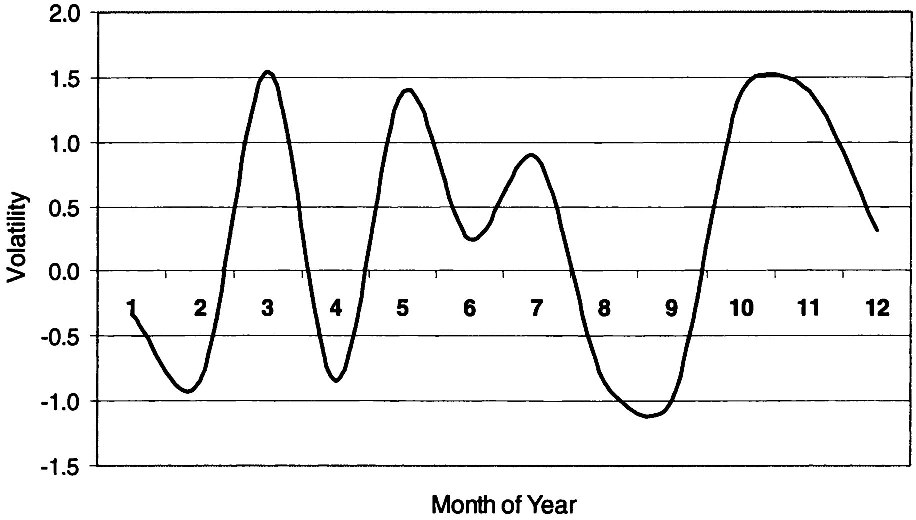

Figure 1. Seasonal pattern in farm-level catfish price volatility across months, 1980–2000

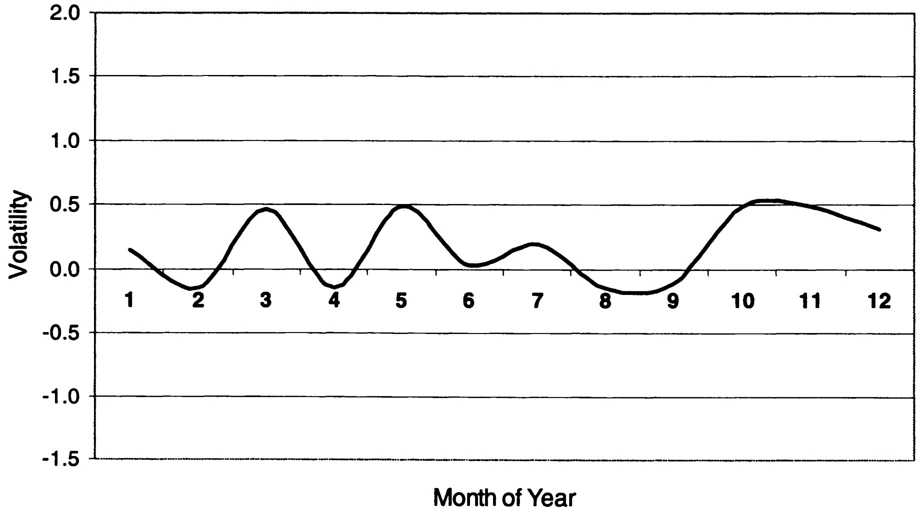

Figure 2. Seasonal pattern in wholesale-level catfish price volatility across months, 1980–2000

Table 5. Univariate EGARCH Models of Volatility Spillover, Monthly Data, 1980–2000

Parameters [a]	Farm	Wholesale	Feed Stuff
α_1	0.51**	0.28**	-0.07
	(8.73)	(3.21)	(-0.75)
α_2	-0.08	0.07	0.12
	(-1.39)	(1.03)	(1.30)
a_0	-13.63**	-2.59**	-0.56
	(-25.51)	(-1.86)	(-1.16)
a_1	0.34**	0.29*	0.27**
	(2.73)	(1.75)	(2.75)
b_1	-0.75**	0.71**	0.95**
	(-12.11)	(4.26)	(15.36)
θ	0.32**	-0.01	-0.09
	(3.62)	(-0.13)	(-0.81)
Spillover from wholesale-level catfish	0.14**	—	—
	(2.26)		
Spillover from farm-level catfish	—	0.19**	—
		(2.64)	
Spillover from feed stuff	0.22**	0.16	—
	(3.55)	(1.35)	
Spillover from menhaden	-0.24**	0.08	0.09
	(-3.13)	(0.57)	(0.76)
Spillover from corn	0.18**	0.01	-0.26*
	(2.07)	(0.06)	(-1.82)
Spillover from soybeans	-0.09	-0.98	0.31*
	(-1.31)	(-0.51)	(1.83)
Log Likelihood	430.66	473.16	371.05
Diagnostics on Standardized and Squared Standardized Residuals:			
Ljung-Box [16]	15.57	24.78	16.57
	(0.486)	(0.112)	(0.413)
Ljung-Box^2 [16]	26.07	8.34	21.16
	(0.090	(0.980)	(0.171)
Jarque-Bera	7.25	1.08	36.71
	(0.030)	(0.580)	(0.000)

Notes: Single and double asterisks (*) denote statistical significance at the 0.05 and 0.01 levels, respectively. In upper portion of table, values in parentheses below parameter estimates are robust t-statistics; in bottom portion of table, numbers in parentheses beneath diagnostic statistics are p-values.

[a] The parameters α_1 and α_2 are the coefficients on the first- and second-order autoregressive processes specified for the mean equations, b_1 is the measure of volatility persistence, and a_1 and a_2 are the measures of the autoregressive conditional heteroskedasticity.

spillover from corn and soybean prices into feed stuff markets, with soybeans having the largest impact. As noted in table 1, catfish feed is generally made up of 32.2% corn and 47.3% soybean meal. Thus, it is not surprising that soybeans would have the largest impact. Finally, all the Ljung-Box statistics for the standardized and squared residuals confirm the univariate EGARCH models with spillover effects are not misspecified (table 5).

Conclusions

This study examines whether there is volatility spillover in the catfish supply chain using monthly price series for catfish (farm and wholesale levels), corn, soybeans, menhaden, and feed stuff prices. The exponential GARCH (or EGARCH) model was used to capture possible spillovers among price series. Unidirectional spillover was assumed between primary inputs (corn and soybeans) and other market levels because of the size of the catfish and feed markets relative to corn and soybean markets. Results show there is significant unidirectional spillover between corn, soybean, and menhaden prices and catfish prices (feed, farm, and wholesale-level fish prices). These results provide evidence of volatility spillovers in an agricultural market, which has received little attention in the literature.

Price transmission through the vertical supply chain is well known, and this study emphasizes the importance of price volatility transmission in market channels as well. These results can have important implications for managers and policy makers. First, the results clearly indicate that policies and events shown to increase volatility in basic commodity markets (corn and soybeans) may have significant effects on vertically related markets (catfish producers and processors). Thus, government policies which destabilize basic markets may destabilize vertically related markets as well.

Second, the findings reveal a potential need to manage the effects of price volatility throughout the supply chain. For example, farm-level prices were receiving significant volatility spillover from input markets (feed) and output markets (wholesale fish). Thus, a comprehensive risk management plan should include both input and output price risk. Because corn price volatility spills over into farm-level catfish prices, the opportunity arises for a potential cross-hedge relationship between catfish and corn prices. If a cross-hedge is not possible, there may be some potential for off-exchange options and cost-of-production insurance.

Finally, the results suggest market structure may have impacts on the asymmetric transmission of volatility. In this case, farmers hold "market power" and transmit asymmetric volatility at the farm level. Although the relative concentration occurs at the processor level, the dominance of cooperative processors suggests farmer-owners are the primary decision makers in this market. Consequently, one might expect that farmers would asymmetrically influence market prices in this type of supply chain. From a broader perspective, this result encourages consideration of volatility transmission asymmetry in future related research.

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References

Aspergis, N., and A. Rezitis. "Asymmetric Cross-Market Volatility Spillovers: Evidence from Daily Data on Equity and Foreign Exchange Markets." *Manchester School*, Supplemental Issue, 69(2001):81–96.

Bailey, D., and B. W. Brorsen. "Price Asymmetry in Spatial Fed Cattle Markets." *West. J. Agr. Econ.* 14(1989):246–52.

Bernard, J., and L. Willett. "Asymmetric Price Relationships in the U.S. Broiler Industry." *J. Agr. and Appl. Econ.* 28(1996):279–89.

Bollerslev, T. "Generalized Autoregressive Conditional Heteroskedasticity." *J. Econometrics* 31(1986): 307–27.

Bollerslev, T., and J. Wooldridge. "Quasi-Maximum Likelihood Estimation and Inference in Dynamic Models with Time-Varying Covariances." *Econometric Rev.* 11(1992):143–72.

Bridge Data, Inc. "CD Compendium of Agricultural Market Prices." Chicago IL: Bridge Data, Inc., 2001.

Byars, J., and D. Peel. "Evidence of Volatility Spillovers in the Interwar Floating Exchange Rate Period Based on High/Low Prices." *Appl. Econ. Letters* 2(1995):394–96.

Dickey, D., and W. Fuller. "Distributions of the Estimators for Autoregressive Time Series with a Unit Root." *J. Amer. Statis. Assoc.* 75(1979):427–31.

Engle, R. "Autoregressive Conditional Heteroskedasticity with Estimates of Variance of United Kingdom Inflation." *Econometrica* 50(1982):987–1007.

Gallagher, L., and C. Twomey. "Identifying the Source of Mean and Volatility Spillovers in Irish Equities: A Multivariate GARCH Analysis." *Econ. and Social Rev.* 29(1998):341–56.

Goodwin, B. K., and M. T. Holt. "Price Transmission and Asymmetry Adjustment in the U.S. Beef Sector." *Amer. J. Agr. Econ.* 81(1999):630–37.

Goodwin, B. K., and R. Schnepf. "Determinants of Endogenous Price Risk in Corn and Wheat Markets." *J. Futures Mkts.* 20(2000):753–74.

Haigh, M., and H. Bryant. "The Effects of Barge and Ocean Freight Price Volatility in International Grain Markets." *Agr. Econ.* 25(2001):41–58.

Haigh, M., and M. T. Holt. "Hedging Foreign Currency, Freight, and Commodity Futures Portfolios: A Note." *J. Futures Mkts.* 22(2002):1205–21.

Hamao, Y., R. Masulis, and V. Ng. "Correlations in Price Changes and Volatility Across International Stock Markets." *Rev. Finan. Stud.* 3(1990):281–307.

Hatch, U., T. Hanson, W. Zidack, R. Lovell, and M. Li. "Economic Analysis of Alternative Protein Levels in Channel Catfish Feed." *Aquaculture Econ. and Mgmt.* 2(1998):13–22.

Hong, Y. "A Test for Volatility Spillover with Application to Exchange Rates." *J. Econometrics* 103(2001):183–224.

Hudson, D., and K. Coble. "Harvest Contract Price Volatility in Cotton." *J. Futures Mkts.* 19(1999): 717–33.

Hudson, D., and T. Hanson. "An Examination of Farm/Processor Price Spreads in Catfish Markets." *Aquaculture Econ. and Mgmt.* 3(1999):222–27.

Kanas, A. "Volatility Spillovers Across Equity Markets: European Evidence." *Appl. Finan. Econ.* 8(1998):245–56.

Kanas, A., and G. Kouretas. "Volatility Spillovers Between Black Market and Official Markets for Foreign Currency in Greece." *J. Finan. Res.* 24(2001):443–61.

Khan, M., and G. Helmers. "Causality, Input Price Variability, and Structural Changes in the U.S. Livestock-Meat Industry." Selected paper presented at the Western Agricultural Economics Association annual meetings, Reno NV, July 1997.

Kim, S., and M. Rui. "Price, Volume, and Volatility Spillovers Among New York, Tokyo, and London Stock Markets." *Internat. J. Bus.* 4(1999):41–61.

Kinnucan, H. "Economic Impacts of Price Variability in the Egg Industry." *J. Food Distribution Res.* 17(1986):77–78.

———. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products." *Amer. J. Agr. Econ.* 69(1987):285–92.

Miller, D., and M. Hayenga. "Price Cycles and Asymmetric Price Transmission in the U.S. Pork Market." *Amer. J. Agr. Econ.* 83(2001):551–62.

Natcher, W., and R. Weaver. "The Transmission of Price Volatility in the Beef Market: A Multivariate Approach." Selected paper presented at the American Agricultural Economics Association annual meetings, Nashville TN, August 1999.

Nelson, D. "Conditional Heteroskedasticity in Asset Returns: A New Approach." *Econometrica* 59(1991): 347–70.

Omega Protein, Inc. Menhaden price data, January 1980 to December 2000. Omega Protein, Inc., Hammond LA. Website online at http://www.buyomegaprotein.com.

Phillips, P., and P. Perron. "Testing for a Unit Root in Time Series Regression." *Biometrika* 65(1998): 335–46.

Pick, D., J. Karrenbrock, and H. Carman. "Price Asymmetry and Marketing Margin Behavior: Arizona Citrus." *Agribus.: An Internat. J.* 6(1990):75–84.

Posadas, B., and B. Dillard. "Operational Characteristics and Costs of Producing Catfish in the Black Belt Area of Mississippi." Res. Rep. No. 203, Dept. of Agr. Econ., Mississippi State University, 1997.

Ray, D. E., J. W. Richardson, D. G. De La Torre Ugarte, and K. H. Tiller. "Estimating Price Variability in Agriculture: Implications for Decision Makers." *J. Agr. and Appl. Econ.* 30(1998):21–33.

Reyes, M. "Asymmetric Volatility Spillover in the Tokyo Stock Exchange." *J. Econ. and Fin.* 25(2001): 206–13.

Susmel, R., and R. Engel. "Hourly Volatility Spillovers Between International Equity Markets." *J. Internat. Money and Fin.* 13(1994):3–25.

Theodossiou, P., and U. Lee. "Mean and Volatility Spillovers Across Major National Stock Markets: Further Empirical Evidence." *J. Finan. Res.* 16(1993):337–50.

Tse, Y. "Price Discovery and Volatility Spillovers and the DJIA Index and Futures Markets." *J. Futures Mkts.* 19(1999):911–30.

U.S. Department of Agriculture, National Agricultural Statistics Service. *Catfish Processing.* USDA/ NASS, Washington, DC. Monthly issues, January 1980 to December 2000.

Vukina, T., and J. Anderson. "A State-Space Forecasting Approach to Optimal Intertemporal Cross-Hedging." *Amer. J. Agr. Econ.* 75(1993):416–24.

Ward, R. "Asymmetry in Retail, Wholesale, and Shipping Point Pricing for Fresh Vegetables." *Amer. J. Agr. Econ.* 62(1982):205–12.

Ward, R., and T. Stevens. "Pricing Linkages in the Supply Chain: The Case for Structural Adjustment in the Beef Industry." *Amer. J. Agr. Econ.* 82(2000):1112–22.

Yang, J., M. Haigh, and D. Leatham. "Agricultural Liberalization Policy and Commodity Price Volatility: A GARCH Application." *Appl. Econ. Letters* 8(2001):593–98.