PRICE TRANSMISSION IN THE CATFISH INDUSTRY WITH SPECIFIC EMPHASIS ON THE ROLE OF PROCESSING COOPERATIVES

JAMES C. O. NYANKORI

The paper presents the implications of farmer-owned processing cooperatives for pricing in the catfish industry and tests hypotheses about the nature of price transmission in the catfish industry. The results of the linear feedback model indicate that causal relationships exist between farm and wholesale prices in the catfish industry. The direction of causality for both frozen and processed whole catfish run from farm to wholesale level.

Key words: cooperatives, pricing, wholesale, retail, linear feedback, causality

INTRODUCTION

The adoption of aquacultural production technology has extended the effects of market forces beyond "wild harvesting" to breeding and production decisions in the catfish industry. As a result, catfish quality has improved, and fluctuations in supply quantity have been reduced. Furthermore, there have been changes in market conduct whereby catfish farmers, through processing cooperatives, exert a considerable degree of market power through vertical integration of production and processing activities. With a majority share of the market, the producer-cooperative has oligopolistic power in the catfish industry, which raises some empirical questions about the nature of price transmission in the catfish industry. How fast and what proportions of autonomous changes in production costs, processing costs and retail prices are transmitted between market levels?

Empirical evidence indicates that the nature of price change transmission through the market channels vary among commodities in accordance with the strength of the linkages between any two successive exchange points (Marsh and Brester; Faminow; Miller; Kinnucan and Forker). On the whole, the linkages tend to be stronger among the prices of perishable, minimally transformable, single-use commodities than among the prices of highly transformable commodities with multiple uses. Relatively few studies have addressed the nature of price transmission where producer-cooperatives have control over two or more market levels.

In this paper, the price linkage between production and wholesale levels were evaluated to test hypotheses about the direction of causality between farm and wholesale prices in the catfish industry. Our methodological approach differs from that of the cross-correlation analysis that has been used in earlier studies of causality.

BACKGROUND AND RELATED ISSUES

The United States farm-raised catfish industry is concentrated in the southeastern states, where Mississippi is the leading producer, followed by Alabama and Arkansas. The industry has grown phenomenally in the last 15 years. During the ten-year period starting in 1975, the industry grew by 28 percent annually, and from 1980 to 1985 the annual growth rate was 33 percent (Hinote).

Two-thirds of the industry product is marketed through specialty restaurants and institutional food distributors, and the rest is sold through retail grocery stores and fish markets. Although the price of farm-raised catfish is relatively stable throughout the year, unit production cost is highly sensitive to feed costs as well as risks due to water quality, disease, parasites, oxygen depletion, and winter kill. These factors have important implications for marketing strategy and price competitiveness of farm-raised catfish in the U.S. market for meats.

An important development in the marketing structure was the formation in the late 1970s of Delta Catfish Processors, a vertically integrated, farmer-owned catfish cooperative which had a 60 percent share of the national catfish market in 1987 (Blackledge). Control over production and processing of catfish has given the cooperative a substantial influence in a number of critical areas including price discovery, returns to farmers, and the competitive position of catfish in the market for meats.

The levels and stability of prices are important elements of price competition. For example, an increase in unit production costs due to higher feed

James C.O. Nyankori is an Associate Professor in the Department of Agriculture Economics, Clemson University, Clemson, South Carolina.

prices, or lower productivity resulting from adverse climatic and environmental conditions shift the primary supply function upwards, which leads to higher farm prices. In a similar fashion, an upward shift in the primary demand function unaccompanied by supply adjustments leads to higher prices in accordance with the price elasticities of demand and supply. The speed and distribution of a price change across market levels have important implications for price levels and stability, and ultimately for price competitiveness.

The catfish industry is relatively new, and information about price transmission in the industry is meager. Farm level variations of the price of catfish can arise directly from a shift in the primary catfish supply function and indirectly from a shift in the primary catfish demand function. Similarly, catfish price changes at the retail level can arise from a shift in the primary demand function and indirectly from a shift in the primary supply function. The magnitudes of the price changes are dependent on the respective price elasticities of demand and supply. However, the direction and speed with which price changes are transmitted between market levels pose an empirical problem that has important implications for production adjustments, as well as for the level and stability of net returns to producers and processors.

The Cooperative is strategically located in the market channel at a point where a significant percentage of catfish converge from producers and radiate to consumers. Consequently, the Cooperative, with its oligopolistic market power, can influence the nature of price transmission in the catfish industry by exerting control over the transmission of a change in the farm or retail price, up or down the market channel, respectively. Specifically, through combinations of market and membership incentives, the Cooperative can realize its self-interests, including maintaining the level and stability of producers' incomes, the surplus fund, and membership bonuses with explicit considerations of the effects of changes in catfish price configuration on pond capacity utilization and expansion possibilities, as well as on industry growth and the competitive position of catfish. In another dimension, the cooperative's location in the main catfish producing region, which also supplies catfish production inputs to other producing regions, gives the Cooperative considerable influence on the national catfish spatial price structure in accordance with theory of basing point pricing (Takayama and Judge, AAEA, Backman).

THE MODEL

The nature of price change transmission in the catfish industry was examined within the context of linear dependence and feedback between time series (Geweke).

Let y_t be an invertible process with an infinite order vector autoregression:

(1) $y_t - \pi y_{t-1} - \pi y_{t-2} - \ldots = \pi(B)y_t = v_t$

where B is a lag operator. Equation (1) can also be expressed as:

(2) $$y_t = \sum_{p=0}^{\infty} \pi_p \, y_{t-p} + v_t, \quad V(v_t) = E(V_t V_s') = \Sigma_v$$

Let $y'_t = (z'_t, x'_t)$ be partitioned into subvectors z_t and x_t to motivate examination of causal relationship between Z and X, both of which can be characterized by the following autoregressive representations:

(3) $$z_t = \sum_{p=1}^{\infty} B_1 \, z_{t-p} + u_{1t}, \quad V(u_{1t}) = \Sigma_1$$

and

(4) $$x_t = \sum_{p=1}^{\infty} E_1 \, x_{t-p} + w_{it}, \quad V(w_{1t}) = \Psi_1$$

where the disturbances, u_{1t}, and w_{1t} are one-step-ahead errors when z_t and x_t are forecast from their own past, respectively.

The linear projection of z_t on Z_{t-1} and X_{t-1}, and of x_t on Z_{t-1} and X_{t-1} (2), can be partitioned as follows:

(5) $$z_t = \sum_{p=1}^{\infty} B_2 \, z_{t-p} + \sum_{p=1}^{\infty} D_2 \, x_{t-p} + u_{2t},$$
$$V(u_{2t}) = \Sigma_2$$

(6) $$x_t = \sum_{p=1}^{\infty} E_2 \, x_{t-p} + \sum_{p=1}^{\infty} F_2 \, z_{t-p} + w_{2t},$$

$$V(w_{2t}) = \Psi_2$$

and Σ_V can be partitioned likewise to produce

$$\Sigma_v = \begin{Bmatrix} T_2 & C \\ C' & \Psi_2 \end{Bmatrix} \quad \text{where } C = E(u'_{2t}, w'_{2t}).$$

If the system (5) - (6) is pre-multiplied by the matrix

$$X = \begin{Bmatrix} I_g & -C\Psi_2^{-1} \\ -C\Psi_2 & I_1 \end{Bmatrix}$$

then in the first g equations of the new system, z_t is a linear function of Z_{t-1}, X_t and a disturbance, $u_{2t} - C\Psi_2 \, w_{2t}$ leading to the linear projection of z_t on Z_{t-1} and X_t (7).

(7) $$z_t = \sum_{p=1}^{\infty} B_{3p}\, z_{t-p} + \sum_{p=0}^{\infty} D_{3p}\, x_{t-p} + u_{3t},$$

$$V(u_{3t}) = \Sigma_3,$$

similarly, the linear projections of x_t on Z_t and X_t are provided by the equations in which x_t is a linear function of Z_t and X_{t-1}:

(8) $$x_t = \sum_{p=1}^{\infty} E_{3p}\, x_{t-p} + \sum_{p=0}^{\infty} F_{3p}\, z_{t-p} + w_{3t},$$

$$V(w_{3t}) = \Psi_3 .$$

Finally, the linear projections of z_t on Z_{t-1} and X, and x_t on Z and X_{t-1} are

(9) $$z_t = \sum_{p=1}^{\infty} B_{4p} z_{t-p} + \sum_{p=-\infty} D_{4p}\, x_{t-p} + u_{4t},$$

$$V(u_{4t}) = \Sigma_4,$$

and

(10) $$x_t = \sum_{p=1}^{\infty} E_{4p}\, x_{t-p} + \sum_{p=-\infty}^{\infty} F_{4p}\, z_{t-p} + w_{4t},$$

$$V(w_{4t}) = \Psi_4 .$$

This set of linear projections has been termed the canonical form of the stationary time series $y'_t = (z'_t, x'_t)$ (Geweke) and is used to define measures of linear feedback from Z to X (9), from X to Z (10), instantaneous linear feedback (11) and linear dependence (12).

If the lag lengths are truncated at p, the likelihood ratio test statistics of the null hypotheses are as follows:

(11) $H_{o1} : F_{x\to z} = 0;\ nF_{x\to\zeta} \sim \chi^2(glp)$;
(X does not cause Z) ;

(12) $H_{o1}\ F_{z\to x} = o;\ nF_{z\to\chi} \sim \chi^2(glp)$;
(Z does not cause X);

where

(13) $F_{x\to z} = \ln(|T_1|/|T_2|) = \ln(|\Psi_3|/|\Psi_4|)$

(14) $F_{z\to x} = \ln(|\Psi_1|/|\Psi_2|) = \ln(|T_3|/|T_4|)$

and the corresponding 95 percent confidence intervals for (13) - (14) are given by (15) - (16).

(15) $$\left\{\left\{\left\{F_{x\to z} - \frac{glp-1}{3n}\right\}^{0.5} - \frac{1.96}{\sqrt{n}}\right\}^2 - \frac{2glp+1}{3n},\ \left\{\left\{F_{x\to z} - \frac{glp-1}{3n}\right\}^{0.5} + \frac{1.96}{\sqrt{n}}\right\}^2 - \frac{2glp+1}{3n}\right\}.$$

(16) $$\left\{\left\{\left\{F_{z\to x} - \frac{glp-1}{3n}\right\}^{0.5} - \frac{1.96}{\sqrt{n}}\right\}^2 - \frac{2glp+1}{3n},\ \left\{\left\{F_{z\to x} - \frac{glp-1}{3n}\right\}^{0.5} + \frac{1.96}{\sqrt{n}}\right\}^2 - \frac{2glp+1}{3n}\right\}.$$

The empirical analysis is based on the catfish price series $P'_t = (PF'_t, PW'_t)$, where (PF'_t, PW'_t) are subvectors of farm and wholesale prices of catfish, respectively. Since most economic time series are not stationary, preliminary analysis of the correlograms of the price series suggested first differencing.

The canonical form for catfish farm and wholesale prices is shown in Table 1. Equations (EC1) and (EC2) are autoregressive specifications of farm and wholesale prices of catfish, respectively. Equations

Table 1. A Canonical Form for the Catfish Farm and Wholesale Prices

Equation	Specification
EC1:	$PF_t = \sum_{p=1}^{3} B_{1p}\, PF_{t-p} + u_{1t}$
EC2:	$PW_t = \sum_{p=1}^{3} E_{1p}\, PW_{t-p} + w_{1t}$
EC3:	$PF_t = \sum_{p=1}^{3} B_{1p}\, PF_{t-p} + \sum_{p=1}^{3} D_{1p}\, PW_{t-p} + u_{2t}$
EC4:	$PW_t = \sum_{p=1}^{3} E_{2p}\, PW_{t-p} + \sum_{p=1}^{3} F_{2p}\, PF_{t-p} + w_{2t}$
EC5:	$PF_t = \sum_{p=1}^{3} B_{3p}\, PF_{t-p} + \sum_{p=0}^{3} D_{3p}\, PW_{t-p} + u_{3t}$
EC6:	$PW_t = \sum_{p=1}^{3} E_{3p}\, PW_{t-p} + \sum_{p=0}^{3} F_{3p}\, PF_{t-p} + w_{3t}$
EC7:	$PF_t = \sum_{p=1}^{3} B_{4p}\, PF_{t-p} + \sum_{p=-3}^{3} D_{4p}\, PW_{t-p} + u_{4t}$
EC8:	$PW_t = \sum_{p=1}^{3} E_{4p}\, PW_{t-p} + \sum_{p=-3}^{3} F_{4p}\, PF_{t-p} + w_{4t}$

Table 2. Parameter Estimates of the Catfish Price Series: Farm and Fresh Wholesale Quarterly Prices: 1980(I) - 1987(IV)

EC1	PF =	1.62499PF1 -	0.92231PF2 +	0.29600PF3	R^{2*} = 0.954	
		(0.1029)	(0.1759)	(0.1019)	D.W. = 1.975	
EC2	PW =	1.32602PW1 -	0.49542PW2 +	0.16798PW3	R^{2*} = 0.960	
		(0.1066)	(0.1707)	(0.1069)	D.W. = 2.057	
EC3	PF =	1.62766PF1 -	0.86502PF2 +	0.19186PF3 -	0.06618PW1 +	0.10921PW2 -
		(0.1090)	(0.2046)	(0.1395)	(0.0716)	(0.0937)
		0.02420PW3	R^{2*} = 0.955			
		(0.0572)	D.W. = 1.957			
EC4	PW =	0.96809PF1 -	0.39259PF2 -	0.28532PF3 +	0.84549PW1 -	0.09493PW2 +
		(0.1598)	(0.2326)	(0.1996)	(0.1056)	(0.1212)
		0.11697PW3	R^{2*} = 0.970			
		(0.0486)	D.W. = 2.015			
EC5	PF =	1.53797PF1 -	0.83135PF2 -	0.22982PF3 +	0.09088PW -	0.14482PW1 +
		(0.1305)	(0.2057)	(0.1424)	(0.0732)	(0.0955)
		0.11774PW2 -	0.03723PW3	R^{2*} = 0.955		
		(0.0936)	(0.0580)	D.W. = 1.950		
EC6	PW =	0.20496PF +	0.65315PF1 -	0.19318PF2 -	0.45692PF3	R^{2*} = 0.970
		(0.1652)	(0.3147)	(0.3380)	(0.2112)	D.W. = 2.019
EC7	PF =	1.41074PF1 -	0.75257PF2 +	0.18875PF3 +	0.04764FPW1 -	0.09198FPW2+
		(0.1012)	(0.1511)	(0.0904)	(0.0447)	(0.0722)
		0.28485FPW3 -	0.17524FPW4	R^{2*} = 0.967		
		(0.0721)	(0.0500)	D.W. = 2.242		
EC8	PW =	-0.21780PW1 +	0.44216PW2 -	0.59239PW3 +	0.68933FPF1 +	1.09760FPF2 -
		(0.1954)	(0.3648)	(0.3680)	(0.2124)	(0.1029)
		0.41571FPF3 +	0.18057FPF4	R^{2*} = 0.966		
		(0.1508)	(0.0951)	D.W. = 2.207		

Note: Standard errors in parentheses.

(EC3), (EC5), and (EC7) are projections of farm price on its own past and that of wholesale price. Similar projections of wholesale price of catfish appear in equations (EC4), (EC6), and (EC8). The projections (EC3) - (EC8) are distinguished by configurations of the lag structures.

The transmission of a change in catfish price between farm and wholesale levels is characterized and measured by the parameters of the distributed lag function (B_{1p}, B_{2p}, B_{3p} , B_{4p}), (D_{1p}, D_{2p}, D_{3p}, D_{4p}), (E_{1p}, E_{2p}, E_{3p}, E_{4p}), and (F_{1p}, F_{2p}, F_{3p}, F_{4p}).

A statistical procedure was applied to determine the lag length, p, since there was neither *a priori* nor substantive basis for the choice of lag lengths. The choice of lag lengths in (EC1) - (EC8) was based solely on conventional statistical criteria used in time series analysis. Specifically, preliminary analyses were performed to aid in the selection of lag length, p, following the methods of Akaike, which suggested three lags (p=3) .

The data used for the analysis were the monthly price series from the Catfish Reports of the National Agricultural Statistics Board of the United States Department of Agriculture for the years 1980 through 1987. The price data were the national averages and were transformed to logarithms prior to estimation since preliminary analysis suggested log-linearity. Equations (EC1) - (EC8) were estimated for farm and wholesale prices of processed catfish, and farm and wholesale prices of frozen catfish.

RESULTS AND CONCLUSIONS

The estimated parameters of the regression equations are presented in Tables 2 and 3. The conventional R^2 is inappropriate in the presence of a lagged dependent variable in the equation. Following Pierce, an adjusted $R^{2*} = 1 - e^{-F}$ ($F = -\log(1-R^2)$ was computed for each equation. The adjusted R^{2*}s for all the equations were high, indicating good explana-

Table 3. Parameter Estimates of the Catfish Price Series: Farm and Frozen Wholesale Quarterly Prices: 1980(I) - 1987(IV)

EC1	PF =	1.62499PF1 -	0.92231PF2 +	0.29600PF3	R^{2*} = 0.948	
		(0.1029)	(0.1759)	(0.1019)	D.W. = 1.975	
EC2	PW =	0.72078PW1 +	0.29750PW2 -	0.01980PW3	R^{2*} = 0.954	
		(0.1073)	(0.1292)	(0.1055)	D.W. = 2.003	
EC3	PF =	1.61492PF1 -	0.92758PF2 +	0.26069PF3 -	0.00383PW1 +	0.06318PW2 -
		(0.1072)	(0.1918)	(0.1205)	(0.0503)	(0.0539)
		0.03917PW3	R^{2*} = 0.955			
		(0.0463)	D.W. = 1.987			
EC4	PW =	0.75786PF1 -	0.29591PF2 -	0.29360PF3 +	0.53851PW1 +	0.35791PW2 +
		(0.2329)	(0.4166)	(0.2617)	(0.1092)	(0.1170)
		0.03586PW3	R^{2*} = 0.960			
		(0.1007)	D.W. = 2.021			
EC5	PF =	1.62263PF1 -	0.93059PF2 +	0.25770PF3 -	0.01017PW +	0.00163PW1 +
		(0.1146)	(0.1935)	(0.1221)	(0.0511)	(0.0576)
		0.06682PW2 -	0.03880PW3	R^{2*} = 0.955		
		(0.0572)	(0.0466)	D.W. = 1.987		
EC6	PW =	-0.04798PF +	0.83534PF1 -	0.34042PF2 -	0.28109PF3 +	0.53832PW1 -
		(0.2412)	(0.4546)	(0.4751)	(0.2707)	(0.1099)
		0.36094PW2 +	0.03398PW3	R^{2*} = 0.960		
		(0.1187)	(0.1017)	D.W. = 2.005		
EC7	PF =	1.5051PF1 -	0.8087PF2 +	0.2049PF3 +	0.0465FPW1 +	0.0206FPW2 +
		(0.014)	(0.687)	(0.065)	(0.0215)	(0.039)
		0.0329FPW3 -	0.0610FPW4	R^{2*} = 0.961		
		(0.061)	(0.097)	D.W. = 2.075		
EC8	PW =	0.6293PW1 +	0.2470PW2 +	0.0314PW3 -	0.2993FPF1 +	0.6220FPF2 -
		(0.057)	(0.133)	(0.178)	(0.219)	(0.513)
		0.4953FPF3 +	0.4023FPF4	R^{2*} = 0.957		
		(0.417)	(0.3072)	D.W. = 2.100		

Note: Standard errors in parentheses.

tory power. The D.W. tests indicated evidence of serial correlation in no equations but equation (EC7). The parameters of the impulse response fit are reported in Table 3.

On the basis of the hypothesis test, $F_{PF\to\pi\delta}$ for farm and wholesale price of fresh catfish as well as farm and wholesale price of frozen catfish, prices were significantly different from zero at the one percent level of significance. The results suggest the existence of the Weiner-Granger causal relationships between farm and wholesale prices of catfish. Specifically, the results indicate that the direction of causality in the catfish industry is from the farm level to the wholesale level for frozen and processed catfish prices with a three-month lag reflecting the well-known partial adjustment process in which market and institutional mechanisms respond fractionally over a period of time to a price change.

The results have important implications for strategies to develop and maintain the competitive position of catfish *vis a vis* other fish and meat products. Specifically, the results suggest that the industry seek and adopt production cost reduction practices with a view to minimizing increases in the wholesale and retail prices. Secondly, the industry would benefit from advertisement and promotions aimed at shifting the demand function for catfish to the right in order to counteract possible effects from price increases, given the configurations of price elasticities of demand for catfish and competing products.

Finally, the catfish industry needs to maintain its involvement in research and development to provide catfish producers and processors with more efficient production and processing technologies, as well as with innovative market pricing strategies. By holding unit farm production cost down, or increasing returns to production resources with present aquacultural technology, and minimizing price variations, the farm price of catfish, and hence wholesale and retail prices, can be maintained at relatively stable and competitive levels.

Table 4. Estimates of Impulse Response Weights for Catfish Prices: Farm, Fresh, and Frozen Wholesale Prices

Dependent Variable	Explanatory Variable	Lag Length (months): 1	2	3
Farm	Fresh	-0.5349 (0.105)	0.0559 (0.120)	0.2452 (0.106)
	Frozen	-0.5368 (0.105)	0.0549 (0.120)	0.2578 (0.106)
Fresh	Farm	-0.2947 (0.113)	0.0700 (0.140)	-0.0079 (0.106)
	Frozen	-0.2277 (0.108)	0.2228 (0.109)	0.1422 (0.138)
Frozen	Farm	0.2877 (0.117)	-0.0657 (0.126)	0.1846 (0.110)
	Fresh	0.3873 (0.108)	-0.0009 (0.115)	0.2804 (0.124)

Note: Standard errors in parentheses.

Table 5. Hypotheses Tests of Linear Feedback Between Farm, Wholesale Processed, and Frozen Prices of Catfish

Hypotheses	Test Statistics	Estimates
1. Farm→processed	$nF_{PF \rightarrow PW(P)}$	0.5061* (0.2590, 0.8262)
2. Farm→frozen	$nF_{PF \rightarrow PW(F)}$	0.2331* (0.0779, 0.4612)
3. Processed→farm	$nF_{PW(P) \rightarrow PF}$	0.0312 (0.0011, 0.1343)
4. Frozen→farm	$nF_{PW(F) \rightarrow PF}$	0.0358 (0.0004, 0.6162)

Note: The asterisks (*) indicate significance at 1 percent level, and the figures in the parentheses are the 95 percent confidence intervals ($g = 1 = 1$; $p = 3$; $n = 92$).

REFERENCES

Akaike, H. "Fitting Autoregressive Models for Prediction." *Ann. Inst. Statist. Math.*, 21 (1969):243-247.

American Agricultural Economics Association. *Federal Milk Marketing Orders: A Review of Research on Their Economic Consequences.* Occasional Paper No. 3. June 1986.

Backman, J. *Price Practices and Price Policies.* N.Y.: The Ronald Press Company, 1953.

Blackledge, R. "Delta's Pride: Catfish Producers Build Successful Mississippi Co-op." *Farmer Cooperatives.* Feb. 1986, pp. 4-5.

Faminow, M.D. "Analysis of the Lead-Lag Structure of Two Wholesale Beef Price Quotes Using Residual Cross Correlation." *North Central Agr. Econ.*, 3(1981):89-94.

Geweke, J. "Measurements of Linear Dependence and Feedback Between Multiple Time Series." *J. Am. Stat. Assoc.*, 77(1982):304-313.

Granger, C. W. J. "Investigating Causal Relations by Econometric Models and Cross Spectral Methods." *Econometrics,* 37(1969):424-438.

Hinote, S. I. "The Status of the Farm-Raised Catfish Industry in the United States." *Aquaculture Digest.* 12(1987):1-3.

Kinnucan, Henry W., and Olan D. Forker. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products." *Am. J. Agr. Econ.*, 67(1985):591-599.

Marsh, John M. and Gary W. Brester. "Short-Term Adjustments in Yellow Sheet Carcass Prices for Red Meats." *Am. J. Agr. Econ.*, 67(1985):591-599.

Miller, Stephen E. "Univariate Residual Cross-Correlation Analysis: An Application to Beef Prices." *North Cent. J. Agr. Econ.*, 1(1979):141-146.

Pierce, D. A. "Comment." *J. Am. Stat. Assoc.*, 77(1982):315-316.

Takayama, T. and G. G. Judge. *Spatial and Temporal Price and Allocation Models.* Amsterdam: North Holland Publishing Company, 1976.

U.S. Department of Agriculture. *Aquaculture Outlook and Situation.* AS-3, April, 1982.