PROCESSOR DEMAND AND PRICE-MARKUP FUNCTIONS FOR CATFISH: A DISAGGREGATED ANALYSIS WITH IMPLICATIONS FOR THE OFF-FLAVOR PROBLEM

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Abstract

Off-flavor in catfish restricts farm marketings 10 to 45% depending on the season. The economic impact on society of this imposed supply restriction depends, in part, on the elasticity of demand for catfish. Econometric estimates based on disaggregated processing plant data indicate an elastic demand at the processor level but an inelastic demand at the farm level. Short-run social welfare gains from the elimination of off-flavor are estimated to equal 12.0% of farm revenues ($10.0 million in 1983). The inelastic demand for catfish at the farm level, however, means that most of the societal gains will accrue to individuals beyond the farm gate. Thus, an economic justification exists for public sector funding of off-flavor research.

Key words: applied welfare analysis, aquaculture, catfish, derived demand, off-flavor, price transmission.

Despite rapid growth in catfish production over the past decade and the emergence of catfish as a profitable alternative enterprise for producers in the South, little is known about basic economic parameters affecting the industry. Econometric studies of supply response have yet to be undertaken. Studies relating to demand focus on Engel curve analysis (Hu; Dellenbarger, Luzar, and Schupp), grocery store demand (Raulerson and Trotter), and wholesale demand (Kinnucan) and as such are too few and limited in scope to permit generalization about elasticities or other demand parameters.

The dearth of empirical evidence relating to demand is especially problematic when attempting to assess the economic significance of off-flavor, generally regarded as the most serious problem facing the industry (Cacho, Kinnucan, and Sindelar). Catfish become "off-flavor" when they absorb flavor compounds, produced by pond organisms, rendering the fish unmarketable for the period of time in which the off-flavor exists (Lovell). Off-flavor is serious because it affects, depending on the season, up to 45% of the foodsize fish held in farmers' ponds; delays harvesting up to eight months[1]; undermines consumers' confidence in the retail product; and, at present, cannot be controlled cost effectively. The problem, moreover, never entirely disappears but is present in varying degrees throughout the year (Table 1). For this reason, off-flavor acts as a type of involuntary supply control. Thus, the effect of off-flavor on aggregate producer incomes and, more generally, on societal welfare depends critically on the price elasticity of demand for catfish.

The research reported in this paper has two purposes: (1) to establish estimates of key de-

[1]Research is too sketchy to make a definitive statement about the length of harvest delay. Preliminary data collected by Lovell suggest an average waiting period of 88 days, but some ponds required up to 240 days to become "on-flavor." If a pond contains a single off-flavor fish, the entire pond is considered unharvestable.

mand and pricing parameters affecting the catfish industry and (2) to determine the potential gains to society of resolving the off-flavor problem. Catfish demand is modeled using a systems approach in which the processing sector is viewed as imperfectly competitive (Kinnucan and Sullivan). The three-equation system, based on a price-setting behavioral hypothesis recently suggested by French and King, is estimated via three-stage least squares to yield elasticities of wholesale-level demand and farm-to-wholesale price transmission. These elasticities are then used to derive an estimate of the farm-level price elasticity. A social welfare function incorporating the farm-level demand elasticity is derived and used to estimate returns to society from lifting the off-flavor imposed supply control.

BACKGROUND INFORMATION AND CONCEPTUAL FRAMEWORK

The demand for catfish at the farm level has three sources: specialty restaurants, fee fishing, and processing plants. Processing plant demand predominates, however, accounting for 80% of farm marketings (USDA, 1982). Hence, in analyzing demand for catfish at the farm level, it is appropriate to focus on processing plant behavior.

Trade, product forms, marketing practices, institutional arrangements, and competition are important factors to consider in modeling processor behavior. In the trade area, U.S. exports of catfish are minimal but imports have been a factor, accounting for 15% of processed sales during the sample period (1980-83). Imported catfish enter the country in processed form and are repackaged and sold to retail grocery outlets (Giachelli). Imported catfish, therefore, compete directly with domestically-processed catfish at the retail level.

Processors sell catfish in two basic product forms, fresh (ice pack) and frozen, representing 60% and 40% of volume, respectively

(Miller, Connor, and Waldrop). To simplify the analysis and permit focusing on farm-level demand, we combined the two product forms into a composite commodity called "processor sales."

Catfish processing is a concentrated industry with five firms accounting for 98% of total pounds processed in 1980 (Miller, Connor, and Waldrop). Advertising and pricing behavior reflect this concentration. In particular, price is determined using a cost-plus process: "Prices are first computed based on the purchase price of the live catfish and the processing, packaging and handling costs. Then, the transportation cost of distributing the fish is added to the above cost to form the base price. This base price is marked up to include a profit. This mark-up is adjusted periodically, based on feedback from the market" (Miller, Connor, and Waldrop, p. 15).

Price at the farm level is influenced by an informal bargaining association which encourages producers not to sell below a preset amount (Dillard). The term "going rate" used to describe this price is suggestive of the effectiveness of the association (Miller, Connor, and Waldrop). Thus, farm price may be viewed as predetermined.

In addition to farm price, imports of catfish and farm-processed supply are assumed to be predetermined. Imports of catfish, primarily from Brazil, are related principally to external forces such as the price of fuel, biological cycles in fish production, U.S.-Brazil exchange rates, and the U.S. consumer price of fish. The farm supply of catfish is predetermined by existing acreage, disease and off-flavor problems, and weather-related production cycles.

As suggested by French and King, when an industry is imperfectly competitive, a model based on a price-setting hypothesis may be more appropriate than the quantity-oriented models of perfect competition. The behavioral assumption of price setting by the processor implies a three-equation system: (1) a (quantity

TABLE 1. INCIDENCE OF OFF-FLAVOR IN FARM-RAISED CATFISH, MISSISSIPPI, 1985-86 SEASONAL AVERAGE

	Month			
Item	January	April	July	October
	---------------------- million pounds ----------------------			
Inventory of foodsize fish	85	48	68	134
Quantity off-flavor	11	5	10	60
On-flavor inventory	74	43	58	74
Incidence of off-flavor (percent)	13	10	15	45

Source: Mississippi Crop and Livestock Reporting Service.

dependent) demand function, (2) a price-markup relation, and (3) an inventory-change identity. The demand function describes movement of the processed product during the marketing period in response to the price set by the processor. Feedback on whether the price set during the marketing period was too high or low occurs in the markup relation via an ending inventory variable. The inventory change identity, which defines ending inventory as equal to beginning inventory plus production less sales, closes the system. The three-equation system consists of three jointly determined variables: processor sales, processor FOB price, and ending inventory.

DATA

Data for six processing plants were made available on a confidential basis for demand estimation. These data underlie the aggregate figures published in the USDA report, *Catfish*. Of the six plants agreeing to release data for the requested period (1980-83), three had data for the entire 48-month period. The other three had 46, 33, and 22 observations, respectively. The plant with 22 observations, because of its small size (less than 5% of market share) and interpretation problems due to limited sample size, was deleted from further analysis.

Summary statistics indicated that these five plants represent 93% of industry volume. Two plants account for over 50% of industry volume, consistent with the findings of Miller, Connor, and Waldrop that catfish processing is highly concentrated. Also consistent with Miller, Connor, and Waldrop, prices paid to farmers tend to be uniform across plants with greater variation in prices charged for the processed product. That processors differ more with respect to output vis-à-vis input prices is consistent with the hypotheses of predetermined farm price and endogenous output price stated previously.

Other data used in the analysis, listed in Table 2, include the U.S. resident population (USDC, Bureau of Census), U.S. disposable personal income (USDC, Bureau of Economic Analysis), the consumer price index (USDL), and imports of catfish (USDA, 1980-83).[2]

EMPIRICAL MODEL

The empirical model consists of three structural equations (see Table 2 for variable definitions):

Processor demand relation:

$$(1) \quad QDN_{it} = a_0 + a_1 RPP_{it} + a_2 RYN_t + a_3 MN_t + a_4 D1_t + a_5 D2_t + a_6 D3_t + \epsilon_{1t}.$$

Price-markup relation:

$$(2) \quad RPP_{it} = b_0 + b_1 RFP_{it} + b_2 RMW_t + b_3 EIN_{it} + b_4 RPP_{it-1} + b_5 D1_t + b_6 D2_t + b_7 D3_t + \epsilon_{2t}.$$

Inventory identity:

$$(3) \quad EIN_{it} - EIN_{it-1} = QHN_t - QDN_{it}.$$

The demand relation expresses total sales by the ith processing plant (QDN) as a function of the real weighted average price of fresh and frozen catfish (RPP), real per capita personal income (RYN), per capita imports of catfish (MN), and seasonality factors (D1, D2, D3). In specifying equation (1), pretests were performed using variables to denote the retail price of fish and meat, grocery store and restaurant wage rates, a lagged dependent variable, trend, and prices charged by processing plants other than the one in question. None of these variables contributed significantly to the explanatory power of the model and each tended to be highly collinear with the RPP or RYN variables; therefore, we selected the more parsimonious demand equation.[3] Pre-testing, of course, implies that t-values from the final model overstate significance levels (Wallace).

Negative coefficients are expected for the own-price and import variables. While ordinarily income is expected to have a positive effect on demand, catfish may be an exception because of its image among some as a low-income food commodity. No *a priori* expectation is placed on the signs of the seasonal dummy coefficients.

Following the price-setting hypothesis, the price-markup relation (equation [2]) specifies

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[2]Details about sources and definition of secondary data are available in a data appendix available upon request from the authors. Terms of agreement, however, prohibit release of data for individual processing plants.

[3]The one exception is the trend term for plant D. This point is discussed later.

TABLE 2. DEFINITIONS OF VARIABLES

Variable type	Symbol	Definition
1. Raw data	N	U.S. total population, millions
	CPI	Consumer Price Index (1967 = 100), all items
	PIP	FOB processor price of ice pack catfish, dollars per pound
	PFZ	FOB processor price of frozen catfish, dollars per pound
	FP	Price paid to farmers for live catfish, dollars per liveweight pound
	QIP	Total monthly sales of ice pack catfish, 1000 pounds
	QFZ	Total monthly sales of frozen catfish, 1000 pounds
	QH	Total quantity of catfish delivered for processing, 1000 liveweight pounds
	EI	End-of-month processor inventory of ice pack and frozen catfish, 1000 pounds
	M	Imports of processed catfish, 1000 pounds
	Y	U.S. disposable personal income
	MW	U.S. minimum wage rate, dollars per hour
2. Endogenous	QDN	Total monthly sales of processed catfish, pounds per 1000, U.S. population ((QIP + QFZ) ÷ N)
	EIN	EI ÷ N
	RPP	Real weighted average price received by processors for ice pack and frozen catfish, in dollars per pound ((k_1PIP + k_2PFZ) CPI, where k_1 = QIP ÷ (QIP + QFZ) and k_2 = QFZ ÷ (QIP + QFZ))
3. Predetermined	QHN	QH ÷ N
	RFP	FP ÷ CPI
	RYN	Y ÷ N ÷ CPI
	MN	M ÷ N
	RMW	MW ÷ CPI
	D1	Shift variable, D1 = 1 if months Jan.–Mar.; zero otherwise
	D2	Shift variable, D2 = 1 if months Apr.–Jun.; zero otherwise
	D3	Shift variable, D3 = 1 if months Jul.– Sept.; zero otherwise
	TR	Time trend, TR = 1, 2, 3, ..., 48 (January 1980 through December 1983)

FOB processor price as a function of input costs, inventory levels, and seasonality factors. Major input costs are hypothesized to be the real price of live catfish (RFP) and the real U.S. minimum wage (RMW). The minimum wage rate is used because most line employees over the sample period received the minimum wage (Giachelli). The ending inventory variable (EIN) is jointly determined with price (RPP) and movement (QDN). The EIN variable reflects the appropriateness of the selected markup.

A lagged dependent variable is specified in the markup equation to capture dynamic processes evident in price transmission equations involving short-interval data (e.g., Kinnucan and Forker). Uncertainty about the reactions of rivals to a price change may cause an individual processing plant to delay setting a new price in response to cost changes. Also, a cost change may be viewed initially as temporary, causing plants to delay re-pricing out-

put. Seasonality variables are included to test the hypothesis that markups are adjusted in response to perceived seasonal shifts in the supply of live catfish and demand for the processed product.

The RFP and RMW variables are expected to have negative coefficients because they reflect costs. Processors are hypothesized to reduce output prices in response to rising inventory; hence, b_3 is expected to be negative. No a priori expectations are placed on the signs of the seasonal binary variables in equation (2) other than the (null) hypothesis that they are jointly zero.

Equations (1) to (3) form a simultaneous equation system. The two behavioral equations are over-identified, lending themselves to estimation by two-stage least squares. However, because error terms in equations (1) and (2) likely are correlated, the equations were estimated as a total system using three-stage least squares.

ESTIMATION RESULTS

The estimated demand and price-markup equations are presented in Table 3.[4] R^2 statistics show the markup specification "explaining" 94% or more of the observed intraplant variation in FOB prices, but there is less explanatory power for the demand equations.[5] Statistics to test for serial correlation are either inconclusive or indicate no serial correlation at the 1% significance level for nine of the 10 estimated equations.[6] Signs of the coefficients generally agree with *a priori* expectations, especially the price and seasonality variables in the demand equation and cost factors and inventory in the markup relation. The key variables in terms of the research objectives of this paper (RPP and RFP) are significant at the 1% level in six of the 10 estimated equations. The lagged dependent variable is of the correct sign and significant at the 5% level or below for all five plants, supporting the hypothesis that changes in input cost are not immediately passed on to buyers.

Before proceeding to a discussion of interplant differences in coefficients, it should be noted that the demand equation for plant D contains a trend term. Unlike the others, plant D enjoyed steady sales growth over the sample period. Examination of the raw data for this plant revealed a steady increase in the proportion of sales described as "further processed," a fact that might explain the sales trend. The positive coefficient for the trend term supports this hypothesis. Moreover, inclusion of a trend term resulted in an estimated own-price effect that conformed more nearly to those of other plants, suggesting that failure to account for time-related changes in product form was biasing the estimate.

Seasonal coefficients tend to differ from zero in both of the estimated equations, suggesting significant seasonality in demand and markup behavior.[7] A regular pattern is observed as well, with coefficients of the demand (markup) equation tending to decline (increase) in value in each succeeding quarter.

Consumer income has an ambiguous effect on catfish demand. Estimated coefficients are significant at the 5% level or lower for only the two plants, A and B. For these two plants, the estimated income effect is negative, consistent with other studies (Hu; Dellenbarger, Luzar, and Schupp). The negative income effect reflects an image problem acknowledged by the industry: catfish is often viewed as a low-income food commodity. Success in overcoming the image problem may be reflected in the positive income effects estimated, albeit less precisely, for plants D and E, the largest of the five. As the largest plants, D and E probably spend more for advertising and promotion to differentiate their products from rivals. Moreover, these two plants have a relatively greater proportion of sales consisting of value-added products. The income coefficients for plants D and E may represent the relative appeal to higher income groups of the more highly processed product forms.

The hypothesis that imports undermine the industry is generally not supported by the statistical results (Table 3). Due to limited markets in which imported catfish compete and their decreasing market share (from 14.9% of industry volume in 1980 to 4.2% in 1983 (USDA, 1980-83)) the general lack of significance of the import effect is not surprising.

Estimated coefficients of ending inventory are negative for all five plants but significant at the 5% level (based on a one-sided t-test) for plants B and E only. Relative to the costs of live fish, labor, and seasonality factors, these results suggest that inventories play a minor role in markup behavior.

PRICE ELASTICITIES

Demand and (long run) price transmission

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[4]The model was estimated initially with pooled data. F-tests indicated significant differences among the five plants in both intercept and (price) slope parameters. This result, coupled with the unbalanced sample size across plants, led to a disaggregated analysis of demand.

[5]The system R^2's (McElroy) were large, varying from .965 (plant E) to .996 (plant D). Individual equation R^2's, based on second stage estimates, are reported because they appear to convey more accurately the explanatory power of each equation.

[6]Reported D.W. and h statistics were computed from first-stage (OLS) estimates. Caution, nonetheless, must be exercised in interpreting the statistics because they generally are not independent across equations, clouding interpretation of the inconclusive region of the test (Theil and Shonkwiler).

[7]The following discussion of the structural equations is restricted to statistical significance of coefficients and agreement of signs with economic logic. Results from the reduced form are presented later, focusing on price effects. A complete matrix of reduced-form coefficients is in an appendix available upon request from the authors.

TABLE 3 PROCESSOR LEVEL DEMAND AND PRICE-MARKUP EQUATIONS FOR CATFISH, 3TLS ESTIMATES, FIVE U.S. PROCESSING PLANTS, 1980–83 SAMPLE PERIOD

								N	R^2	D.W.	h	S^b
Plant A												
1. QDN =	36.175 (3.72)[a]	−.0212 RPP (−1.38)	+.0254 MN (.47)	−8.4238 RYN (−3.46)	+.9402 D1 (3.74)	+.4014 D2 (1.61)	+.3093 D3 (1.20)	45	.370	1.21	——	.558
2. RPP =	−37.549 (−2.51)	+.2291 RFP (1.31)	+52.084 RMW (2.59)	−2.0508 EIN (−1.20)	+.5326 RPP$_{-1}$ (4.58)	−2.2064 D1 (−1.81)	−1.0034 D2 (−1.01)	+.0022 D3 (.002)	45	.937	——	−.61	1.979
Plant B												
3. QDN =	17.244 (3.20)	−.0431 RPP (−3.91)	−.0747 MN (−2.25)	−3.3981 RYN (−2.58)	+.7951 D1 (5.54)	+.3819 D2 (2.57)	+.2641 D3 (1.75)	47	.622	1.78	——	.334
4. RPP =	−17.554 (−2.88)	+.0758 RFP (1.19)	+26.326 RMW (3.19)	−1.0660 EIN (−1.86)	+.7592 RPP$_{-1}$ (11.45)	−1.8313 D1 (−3.84)	−1.6032 D2 (−3.59)	−.6398 D3 (−1.86)	47	.986	——	−3.51	.788
Plant C												
5. QDN =	18.658 (2.29)	−.0758 RPP (−5.65)	−.0503 MN (−.91)	−2.9554 RYN (−1.44)	+.9574 D1 (4.11)	+.6299 D2 (2.67)	+.4949 D3 (2.07)	47	.629	1.98	——	.542
6. RPP =	−30.385 (−3.09)	+.6282 RFP (4.61)	+41.829 RMW (4.05)	−.5960 EIN (−.84)	+.4774 RPP$_{-1}$ (5.62)	−1.4496 D1 (−2.48)	−.8218 D2 (−1.69)	−.7729 D3 (−1.66)	47	.984	——	.62	1.117
Plant D												
7. QDN =	−41.525 (−3.51)	−.1400 RPP (−1.76)	−.3196 MN (−1.97)	+7.944 RYN (1.73)	+.1276 TR (3.85)	+.0329 D1 (.09)	+.1897 D2 (−.56)	−.0239 D3 (−.07)	32	.901	2.34	——	.660
8. RPP =	−22.128 (−2.83)	+.9632 RFP (5.17)	+37.680 RMW (8.84)	−.7167 EIN (−1.49)	+.2258 RPP$_{-1}$ (1.85)	−.9128 D1 (−2.52)	−.7198 D2 (−2.45)	+.2772 D3 (1.04)	32	.984	——	−1.06	.498
Plant E												
9. QDN =	−3.691 (−.29)	−.0988 RPP (−3.99)	+.0406 MN (.48)	+3.299 RYN (1.06)	+1.2668 D1 (3.66)	+1.0076 D2 (2.84)	+.6687 D3 (1.89)	47	.494	2.22	——	.806
10. RPP =	10.391 (−.56)	+.3653 RFP (2.91)	+35.128 RMW (1.92)	−1.965 EIN (−1.72)	+.3929 RPP$_{-1}$ (2.88)	−.1011 D1 (−.09)	−1.8204 D2 (−2.11)	−.4865 D3 (−.53)	47	.952	——	−1.43	1.652

Summary Statistics

[a]Numbers in parentheses are coefficients divided by respective asymptotic standard errors.

[b]Standard error of the regression.

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elasticities, evaluated at data means, were computed from the analytically derived reduced forms using the procedure described by Chavas, Hassan, and Johnson. This procedure involves manipulating the system so that the endogenous variable RPP in the derivative $\partial QDN/\partial RPP$ can be treated as "conditionally exogenous." Elasticities so computed are interpreted as "total elasticities" because they measure the percent change in one endogenous variable (QDN or RPP) per one percent change in another endogenous or exogenous variable (RPP or RFP), allowing all other relevant variables in the system to adjust accordingly.

Estimated demand elasticities range from $-.44$ to -1.59 but tend to cluster around -1.5, indicating that the demand curve faced by catfish processors is price elastic. This finding is consistent with an earlier study showing catfish demand at retail to be price elastic with an estimated coefficient of about -2.5 (Raulerson and Trotter). Kinnucan estimated an elasticity at wholesale of between $-.85$ and -2.37, depending on the point of evaluation along the demand curve, but the elasticity at data means was estimated to be -1.54.

Transmission elasticities showing the linkage between farm and FOB processor price range from .09 for plant B to .44 for plant D. The wider variation across plants in transmission vis-à-vis demand elasticities is consistent with the price-setting hypothesis. Control over output prices permits deployment of pricing strategies to gain market share. Potential payoffs (and risks) to tinkering with price policy are enhanced when product differentiation is minimal, as appears to be the case with catfish because demand

elasticities across firms are similar (Table 4).

A parameter important for determining the economic implications of off-flavor (to be discussed later) is the farm-level demand elasticity for catfish. Assuming a Leontif-type catfish processing technology (i.e., live fish and other inputs are combined in fixed proportions to produce the processed product), the farm-level elasticity is the product of the wholesale elasticity and the farm-to-wholesale elasticity of price transmission (Gardner). The farm-level elasticities derived in this manner range from $-.08$ for plant A to $-.69$ for plant D, indicating an inelastic demand for catfish at the farm level (Table 4). Weighting the plant-specific estimates by respective (sample) market shares and summing yields an aggregate farm-level demand elasticity of $-.37$. This estimate is somewhat below the lower bound estimate of Raulerson and Trotter ($-.65$) but is plausible given the time differences of the two studies. The industry has grown substantially since 1972 with concomitant increases in processing plant size and technical sophistication. The specialized nature of modern processing plants means no substitutes exist for live catfish at the plant level. This fact, coupled with a processing-level demand elasticity that just exceeds unity, strengthens the notion of an inelastic demand at the farm level.

IMPLICATIONS FOR OFF-FLAVOR

It was argued previously that off-flavor, by reducing the supply of marketable fish, acts as a type of (involuntary) supply control. Moreover, since off-flavor affects fish throughout the year, the supply control is in effect continuously.[8] This existence of a con-

TABLE 4. DEMAND AND PRICE TRANSMISSION ELASTICITIES FOR CATFISH, FIVE U.S. PROCESSING PLANTS, BASED ON 1980-83 DATA

Plant	Processor-level demand elasticities[a]	Farm-plant price transmission elasticities[a]	Farm-level demand elasticities
A	$-.44$	.18	$-.08$
B	-1.50	.09	$-.14$
C	-1.59	.41	$-.65$
D	-1.56	.44	$-.69$
E	-1.22	.19	$-.23$
A–E[b]	-1.28	.29	$-.37$

[a]Evaluated at mean data points.

[b]Computed as a weighted average of preceding elasticities with plant market shares serving as weights.

[8]The fact that off-flavor is present throughout the year and is not restricted to a particular season is important for modeling purposes. In particular, if off-flavor occurred intermittently—present in one season and absent in another—then a seasonal model is appropriate because off-flavor would simply reallocate supplies across seasons without affecting total supply. But the continuous presence of off-flavor means that average annual supplies of foodsize fish are restricted, justifying the modeling procedure adopted in this paper. Still, it is possible that an appropriately specified seasonal model, perhaps incorporating the effects of demand shifts, could refine our welfare estimates.

tinuous restriction on farm marketings of cat-fish, coupled with an inelastic demand for cat-fish at the farm level, implies that a new technology solving the off-flavor problem (say a chemical to treat pond water) may not be in the best interest of catfish producers.

Industry success in obtaining public funding for research on off-flavor implies a need to know whether the potential gain in consumer welfare from the research is sufficient to off-set potential producer losses so that a net welfare gain can accrue to society as a result of the investment.

While a definitive answer to the question of public benefits from off-flavor research re-quires knowledge of catfish supply elasticities and better information about the actual reduc-tion in farm marketings, an estimate of the *short-run* social welfare impact is possible if one accepts certain assumptions. These are: (a) the demand curve is linear, (b) the farm-level demand elasticity is $-.37$, (c) the annual reduction in farm marketings caused by off-flavor is 15%, (d) elimination of off-flavor does not shift the demand curve, and (e) the concepts of producer and consumer surplus are valid measures of social welfare at the farm level.

These assumptions are treated as maintain-ed hypotheses to facilitate computing welfare estimates. It should be noted, however, that assumptions (a) and (b) are made for conve-nience and not necessarily accepted as facts. If assumption (d) is not correct (i.e., if elimina-tion of off-flavor increases the demand for cat-fish, which is likely because consumer con-fidence in the product would increase), then the welfare measures *understate* the actual cost of off-flavor. Relaxation of assumption (a) might either increase or decrease the welfare estimate, *ceteris paribus*. Sensitivity analysis is performed to determine the economic implications of assumptions (b) and (c). Finally, the social welfare estimates refer strictly to short-run (fixed supply) effects.

With these caveats in mind, the following equation was derived to estimate the social welfare effect of eliminating off-flavor (see Ap-pendix):

$$(4) \quad SW' = \frac{\tau \, [a_0 + \frac{1}{2} a_1 Q_0 \, (\tau + 2)]}{a_0 + a_1 Q_0} \quad ,$$

where

SW'=change in net social welfare (defined

as the sum of the changes in con-sumer and producer surplus) ex-pressed as a proportion of initial equilibrium farm revenues;

τ=the magnitude of the supply restric-tion expressed as a proportion of in-itial farm marketings;

Q_0=initial farm marketings before relax-ation of the supply restriction; and

a_0, a_1=intercept and slope, respectively, of the (inverse) demand function $P = a_0 + a_1 Q$.

To implement equation (4), values for the de-mand parameters are required. These were obtained from the following equations:

$$(5) \quad a_0 = P_0(1 - 1/\eta), \text{ and}$$

$$(6) \quad a_1 = P_0/\eta Q_0,$$

where η is the farm-level demand elasticity, and P_0 and Q_0 are the average farm price and farm marketings, respectively, for the time period in question.

The value for $\Delta SW'$, based on 1983 data points ($P_0 = \$.61$ per pound, liveweight; $Q_0 = 137.2$ million pounds liveweight [USDA, 1983]) and assumptions (b) and (c), is .120. This result means that the short-run gain in social welfare in 1983 is estimated to represent 12.0% of farm revenues. Based on 1983 farm revenues of \$83.7 million, this estimate implies an ab-solute potential gain to society of \$10.0 million if off-flavor could be eliminated.

Sensitivity analysis illustrated in Table 5 shows the welfare estimates robust with respect to the demand elasticity, but sensitive to assumptions about the magnitude of the supply restriction. This suggests that improv-ed estimates of the social cost of off-flavor will depend more on obtaining better information about the extent to which off-flavor reduces farm marketings than on obtaining more reliable estimates of the demand elasticity.

CONCLUSIONS

The demand and price-markup functions estimated in this study suggest that demand for catfish is elastic at the processor level but inelastic at the farm level. These results have implications for the off-flavor problem affect-ing the industry. With an inelastic farm-level demand, the increased farm marketings that would follow from the elimination or effective control of off-flavor would reduce total

Demand elasticity (η)	Supply restriction (τ)	Estimated change in social welfare[a] (ΔSW)
	---- percent ----	---- percent ----
− .37	15	12.0
− .19	15	10.1
− .74	15	13.8
− .37	10	8.9
− .37	20	15.6

[a]These figures are expressed as a percent of 1983 farm revenues.

revenues received by catfish producers. Revenues received by catfish producers represent cost to processors, thereby decreasing aggregate expenditures for fish by processors. The reduced cost of live fish coupled with economies of size realized from higher volume processing (Fuller and Dillard) suggest substantial cost savings to the processing sector. Moreover, with lower production costs at producer and processor levels, catfish prices at retail could be reduced, resulting in a more than proportional increase in retail sales (because of an elastic demand). Expanded industry volume would permit utilization of larger plants capable of capturing the scale economies that appear to be important in catfish processing (Fuller and Dillard).

While this assessment of the economic implications of off-flavor is *ex ante* in character and limited, strictly speaking, to short-run impacts, it does provide a useful first approximation to the societal cost of the problem. The magnitude of the estimated short-run welfare costs (12.0% of farm revenues) corroborates industry perceptions that off-flavor is a pressing problem. The findings suggest that research to solve off-flavor could yield attractive returns both to industry and society.

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APPENDIX

The formula to measure the net social welfare change associated with increased marketings can be derived with the aid of the following figure.
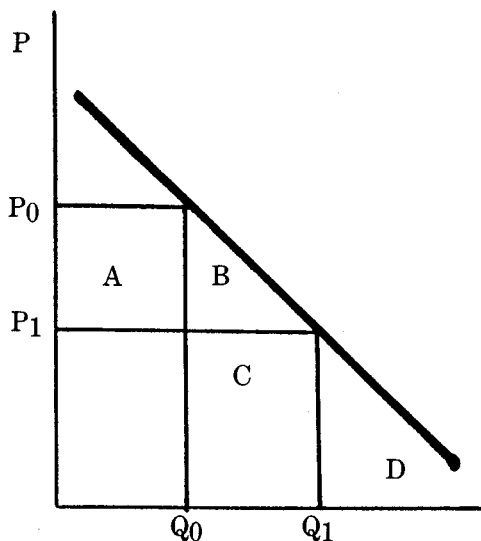
In the diagram, an increase in marketings from Q_0 to Q_1 lowers price from P_0 to P_1. As a result of the lower price, consumer surplus (CS) increases by the areas A + B. The change in producer surplus (PS) (which is equivalent to total revenue when supply is perfectly inelastic) is represented by the area C − A. Note that unless demand is price elastic within the relevant

range, the increased marketings will reduce producer surplus. The net change in social welfare (SW) is defined as the sum of the changes in consumer and producer surplus or: $\Delta SW = \Delta CS + \Delta PS =$ area B + C.

The area of B + C can be determined as follows. First, let the linear demand curve be represented by:

(7) $P = a_0 + a_1 Q$.

For convenience, let:

(8) $Q_1 = Q_0 + \tau Q_0 = Q_0(1 + \tau)$,

where τ is the proportional (not percentage) increase in marketings relative to the initial equilibrium level Q_0. The area under the demand curve between Q_0 and Q_1 is then:

$$\text{area (B + C)} = \int_{Q_0}^{Q_0(1 + \tau)} (a_0 + a_1 Q) dQ.$$

Solving the integral and simplifying yields:

(9) $\Delta SW = \tau Q_0 [a_0 + \frac{1}{2} a_1 Q_0 (\tau + 2)]$.

It is sometimes more convenient to measure changes in welfare in terms of deviations from initial total revenue. To express equation (9) in terms of initial total revenue $(P_0 Q_0)$, first note by equation (7) that:

(10) $P_0 Q_0 = (a_0 + a_1 Q_0) Q_0$.

Letting $\Delta SW' = \Delta SW / P_0 Q_0$, dividing both sides of equation (9) by equation (10) and simplifying yields:

(11) $$\Delta SW' = \frac{\tau [a_0 + \frac{1}{2} a_1 Q_0 (\tau + 2)]}{a_0 + a_1 Q_0}.$$

Equation (11) is an exact expression for relative welfare change assuming fixed supply and linear demand. If equation (11) is multiplied by 100, it expresses welfare change as a percent of initial industry revenues.