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Econometric Analysis of Demand and Price-Markup Functions for Catfish at the Processor Level

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Econometric Analysis of Demand and Price-Markup Functions for Catfish at the Processor Level[1]

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INTRODUCTION

CATFISH PRODUCTION in the United States more than quadrupled between 1980 and 1987—from 60 to 280 million pounds liveweight *(22)*. Despite this rapid growth and the emergence of catfish as a profitable enterprise for producers in the South, little is known about basic economic parameters governing the industry. Empirical supply relationships for catfish have yet to be established. Studies of demand have begun to emerge and have been useful in indicating how changes in income affect consumer demand *(9,3)*; how price affects retail grocery store sales *(19)*; and how processing plant sales are affected by price and seasonality factors *(12)*. Yet even the demand studies are too few and specialized to permit generalization about price elasticities and other key demand parameters.

Knowledge of supply and demand elasticities is essential for improved understanding of the effects of technical change, industry growth processes, pricing behavior, and the impacts of government regulation. For example, new farm technology favors consumers more than producers if the commodity in

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question has an inelastic demand (elasticity coefficient less than one in absolute value). This fact serves as a basic rationale for government support of agricultural research. Too, the efficacy and costliness of a government price support scheme hinge on the magnitude of supply and demand elasticities. A price support program for an industry with an elastic demand (elasticity coefficient greater than one in absolute value) is counter-productive because industry revenues are reduced as price is increased. If demand is price inelastic, but supply is price elastic, the price support scheme will prove costly to the U.S. Treasury. Supply (demand) elasticities, by telling how industry revenues (consumer expenditures) respond to price, are useful to industry analysts and policy makers for prediction and planning purposes.

The primary purpose of the research reported in this bulletin is to provide empirical estimates of the price elasticity of demand for catfish at processor and farm levels of the market. A secondary purpose is to indicate the usefulness of a new modeling procedure for estimating demand relationships for industries characterized by imperfect competition. As a byproduct of the analysis, empirical estimates are obtained of processors' price-markup behavior.

A brief description of the market environment and operating practices of processing plants sets the stage for the econometric analysis of demand. Based on this background information, a three-equation system is specified in which the processor is viewed as a price-setter. The system is estimated via three-stage least squares using disaggregated data for five plants. Elasticities for wholesale and farm level demand and farm-wholesale price transmission are derived from the reduced form of the structural model. The final section discusses implications of the estimated elasticities and presents suggestions for further research.

BACKGROUND INFORMATION FOR DEMAND ANALYSIS

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 percent of farm marketings in 1980 *(21)*. Hence, in analyzing demand for catfish at the farm level, it is appropriate to focus on processing plant behavior.

Trade, product forms, marketing practices, data characteristics, institutional arrangements, and competition are important factors to consider in modeling processor behavior. Exports of catfish are of minimal importance in the trade area, but imports have been a factor, accounting for 15 percent of processed sales during the sample period (1980-83). Imported catfish enter the country in processed form where they are repackaged and sold to retail grocery outlets *(8)*. Hence, imported catfish compete directly with domestically processed catfish at the retail level.

Catfish is sold in two basic product forms, fresh (ice pack) and frozen. In 1979, 60 percent of processor sales was fresh and the remaining 40 percent was frozen *(17)*. The primary outlets for fresh fish are grocery stores and specialty restaurants. Most frozen fish move through the food service industry *(17)*. Processor inventories primarily consist of the frozen product. While it might be useful to consider separate demands for the three market outlets (food service, specialty restaurant, and grocery store) separated by product category (fresh and frozen), data are insufficient to permit such a detailed analysis. To simplify the analysis and focus on aggregate demand at the farm level, the two product forms were combined into a composite called "processor sales."

Processing plants sell the majority of their fish through food brokers *(17)*. Advertising is an important marketing instrument. Importantly, price is determined using a cost-plus process, as explained by Miller et al. *(17*, p. 15): "Prices are first computed based on the purchase price of the live catfish and the processing, packaging and handling costs. Then, the transportation cost . . . is added . . . 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."

While processors set FOB prices, the price paid for the raw fish input appears to be taken as given.[4] The term "going rate" to describe the price processors pay for live catfish supports the hypothesis that farm price is predetermined *(17)*. This attitude on the part of processors that farm prices are given may reflect the influence of an informal bargaining

[4]The assumption of predetermined farm price could be questioned because of evidence of monopsonistic behavior at the processor level (14) but that evidence pertains to recent industry experience (post 1984) and relates to only a small segment of the industry. The shortness of the data interval (1 month) bolsters the assumption of predetermined farm price, perhaps *a fortiori*.

association which encourages producers not to sell fish for a price lower than a preset amount *(4)*.

Finally, catfish processing is a concentrated industry. A 1980 industry survey by Miller et al. *(17)* found that five firms accounted for 98 percent of total pounds processed. The authors concluded that ". . . the industry is characterized structurally by a high degree of market concentration . . ." Because of the imperfectly competitive nature of the catfish processing industry, the model developed below is based on a price setting behaviorial hypothesis.

DEMAND ESTIMATION

Conceptual Framework

As suggested by French and King (5), 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 implies a three-equation system: (1) a (quantity 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 too 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.

In addition to farm price, imports of catfish and farm 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, off-flavor problems[5], and weather-related production cycles.

[5]Industry data indicate that 5 to 10 percent of foodsize fish are lost each year to diseases and oxygen depletion of ponds (18). Because of the long period in which off-flavor fish must be held in ponds before the problem dissipates [88 days on average according to data collected by Lowell (16)] and its continuous presence, off-flavor importantly affects the supply of foodsize fish (20).

TABLE 1. SUMMARY STATISTICS FOR FIVE U.S. CATFISH PROCESSING PLANTS, 1980-83

Plant	Price paid for live fish (RFP)/lb.[1]	FOB processor price/lb.[1]		Weighted FOB processor price (RPP)/lb.[1]	Average monthly processed product sales (QDN)/1,000 U.S. population	Average monthly inventory (EIN)/1,000 U.S. population	Proportion of sales		Market shares	
		Ice pack fish (PIP)	Frozen fish (PFZ)				Frozen	Further processed	Sample	Industry
	Cents	*Cents*	*Cents*	*Cents*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
A	22.6	52.2	64.7	57.3	2.76	1.19	41.4	10.3	16.8	15.7
B	20.7	55.2	59.6	57.8	1.66	.71	60.5	3.0	10.1	9.4
C	22.4	61.0	61.0	61.0	2.90	1.75	79.3	11.8	17.6	16.4
D	20.9	51.3	52.2	51.8	4.66	1.99	48.2	21.3	28.3	26.4
E	22.6	54.7	57.7	55.5	4.49	2.52	28.9	14.2	27.2	25.5
Total...	—	—	—	—	—	—	—	—	100.0	93.4

Source: Confidential data provided to the authors by the USDA under authority of the indicated plants.
[1]1967 dollars.

Data

Data for six processing plants were made available on a confidential basis for demand estimation. These data underlie the aggregate figures published by the USDA monthly report, *Catfish*. Of the six plants agreeing to release data for the requested period (1980-83), three had data for the entire 4-year period. Of the other three, two appeared to be new entrants, providing 33 and 22 monthly observations. The remaining plant appeared to have either discontinued operations or to have stopped providing data, in any case yielding 46 observations. Because of its small size (less than 5 percent of market share) and the likelihood of interpretation problems due to limited sample size, the plant with 22 observations was deleted from further analysis.

Summary statistics indicate that the five remaining plants represented 93 percent of industry volume over the time period in question, table 1. Two plants (D and E) accounted for over 50 percent of industry volume, consistent with the findings of Miller et al. *(17)* that catfish processing is highly concentrated. Also consistent with Miller et al. *(17)*, prices paid to farmers tended to be uniform across plants with greater variation in prices charged for the processed product. That processors differ more with respect to output vis-a-vis input prices is consistent with the hypotheses of predetermined farm price and endogenous output price. Of note, too, are the substantial differences among plants in the percentage of product sold in frozen versus "further processed" forms. These differences are useful in interpreting differences in plant-specific demand elasticities presented later.

Other data used in the analysis, listed in table 2, include the resident population of the United States *(24)*, U.S. disposable personal income *(23)*, the consumer price index *(25)*, the U.S. minimum wage rate, and imports of catfish *(22)*[6].

Empirical Model

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

[6]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 the individual processing plants.

Processor demand relation:

$$(1)\ QDN_{it} = a_O + a_1RPP_{it} + a_2RYN_t + a_3MN_t + a_4D1_t + a_5D2_t + a_6D3_t + n_{1t}.$$

Price-markup relation:

$$(2)\ RPP_{it} = b_O + b_1RFP_{it} + b_2RMW_t + b_3EIN_{it} + b_4RPP_{it-1} + b_5D1_t + b_6D2_t + b_7D3_t + n_{2t}.$$

Inventory identity:

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

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 for 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, in 1,000 pounds
	QFZ	Total monthly sales of frozen catfish, in 1,000 pounds
	QH	Total quantity of catfish delivered for processing, in 1,000 liveweight pounds
	EI	End-of-month processor inventory of ice pack and frozen catfish, in 1,000 pounds
	M	Imports of processed catfish in 1,000 pounds
	Y	U.S. disposable personal income
	MW	U.S. minimum wage in dollars per hour
2. Endogenous variables	QDN	Total monthly sales of processed catfish, pounds per 1,000 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.-June; zero otherwise
	D3	Shift variable, D3=1 if months July-Sept.; zero otherwise
	TR	Time trend, TR=1,2,3,...,48 (Jan. 1980 through Dec. 1983)

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 (D_1, D_2, D_3). 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 (with the exception of trend, to be discussed later) contributed significantly to the explanatory power of the model and each tended to be highly collinear with the RPP or RYN variables. We selected, therefore, the more parsimonious specification. Pretesting, of course, implies that t-values from the final model overstate significance levels *(26)*.

The coefficients of the price and import variables are expected to have a negative sign. While income ordinarily is expected to have a positive net effect on demand, catfish may be an exception because of its image among some as a low income food commodity. Demand for catfish is hypothesized to change seasonally; therefore, nonzero coefficients are expected for the seasonal binary variables.

Under the behavioral hypothesis that catfish processing plants do not take output prices as given but instead set these prices based on cost and profit considerations, the price-markup relation (Equation (2)) specifies FOB processor price as a function of input costs, inventory levels, and seasonality factors. The major input costs of concern to the processing plant are hypothesized to be the real price of live catfish (RFP) and the real U.S. minimum wage rate (RMW). The minimum wage rate is used to indicate labor costs because line employees over the sample period generally were paid the minimum wage *(8)*. The ending inventory variable (EIN) is jointly determined with price (RPP) and movement (QDN). EIN 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 based on short-interval data *(13)*. Uncertainty about reactions of rivals to a price change may cause the processing plant to delay setting a new price in response to cost changes. Too, a cost change may be viewed initially as temporary, causing plants to delay repricing output until adequate time has elapsed to ensure that the cost change is permanent. Seasonality variables are included to test the hypothesis that plants adjust markups in response to perceived seasonal shifts in the supply of live catfish and demand for the processed product.

Because the RFP and RMW variables reflect costs, their coefficients are expected to have positive signs. 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 equal to 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 for each processing plant are presented in table 3. R^2 statistics show the markup specification "explaining" 94 percent or more of the observed intraplant variation in FOB prices but less explanatory power for the demand equations. Statistics to test for serial correlation are either inconclusive or indicate lack of serial correlation at the 1 percent significance level for 9 of the 10 estimated equations. In general, signs of the coefficients agree with *a priori* expectations, especially with respect to price and seasonality variables in the demand equation and cost factors and inventory in the markup relation. Significance levels for the price variables (RPP and PFP) in general are high, exceeding 1 percent in 6 of the 10 estimated equations.[7] The lagged dependent variable is of the correct sign and significant at the 5 percent level or below for all plants, supporting the hypothesis that changes in input cost are not immediately passed on to buyers of processed catfish. In fact,

[7]The demand equation for plant D differs from the others by an added 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 classified as "further processed." A trend term was included to capture this gradual change in the structure of firm D's output. Though the trend term reduced the precision of the estimated price effect for Plant D (the t-ratio declined from -7.44 to -1.76), the elasticity estimate conformed more nearly to that of the other plants.

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

Equations, by plant									Summary Statistics				
									N	R^2	D.W.	h	SE[2]
Plant A													
1. QDN =	36.175	-.0212 RPP	+.0254 MN	-8.4238 RYN	+.9402 DI	+.4014 D2	+.3093 D3		45	.370	1.21	—	.558
	(3.72)[1]	(-1.38)	(.47)	(-3.46)	(3.74)	(1.61)	(1.20)						
2. RPP =	-37.549	+.2291 RFP	+52.084 RMW	-2.0508 EIN	+.5326 RPP_{-1}	-2.2064 DI	-1.0034 D2	+.0022 D3	45	.937	—	-.61	1.979
	(-2.51)	(1.31)	(2.59)	(-1.20)	(4.58)	(-1.81)	(-1.01)	(.002)					
Plant B													
3. QDN =	17.244	-.0431 RPP	-.0747 MN	-3.3981 RYN	+.7951 DI	+.3819 D2	+.2641 D3		47	.622	1.78	—	.334
	(3.20)	(-3.91)	(-2.25)	(-2.58)	(5.54)	(2.57)	(1.75)						
4. RPP =	17.554	+.0758 RFP	+26.326 RMW	-1.0660 EIN	+.7592 RPP_{-1}	-1.8313 DI	-1.6032 D2	-.6398 D3	47	.986	—	-3.51	.788
	(-2.88)	(1.19)	(3.19)	(-1.86)	(11.45)	(-3.84)	(-3.59)	(-1.86)					
Plant C													
5. QDN =	18.658	-.0758 RPP	-.0503 MN	-2.9554 RYN	+.9574 DI	+.6299 D2	+.4949 D3		47	.629	1.98	—	.542
	(2.29)	(-5.65)	(-.91)	(-1.44)	(4.11)	(2.67)	(2.07)						
6. RPP =	-30.385	+.6282 RFP	+41.829 RMW	-.5960 EIN	+.4774 RPP_{-1}	-1.4496 DI	-.8218 D2	-.7729 D3	47	.984	—	.62	1.117
	(-3.09)	(4.61)	(4.05)	(-.84)	(5.62)	(-2.48)	(-1.69)	(-1.66)					
Plant D													
7. QDN =	-41.525	-.1400 RPP	-3.196 MN	+7.944 RYN	+.1276 TR	+.0329 DI	+.1897 D2	-.0239 D3	32	.901	2.34	—	.660
	(-3.51)	(-1.76)	(-1.97)	(1.73)	(3.65)	(.09)	(-.56)	(-.07)					
8. RPP =	-22.128	+.9632 RFP	+37.680 RMW	-.7167 EIN	+.2258 RPP_{-1}	-.9128 D1	-.7198 D2	+.2772 D3	32	.984	—	-1.08	.498
	(-2.83)	(5.17)	(8.84)	(-1.49)	(1.85)	(-2.52)	(-2.45)	(1.04)					
Plant E													
9. QDN =	-3.691	-.0988 RPP	+.0408 MN	+3.299 RYN	+1.2668 D1	+1.0076 D2	+.6687 D3		47	.494	2.22	—	.808
	(-.29)	(-3.99)	(.48)	(1.06)	(3.66)	(2.84)	(1.89)						
10. RPP =	10.391	+.3653 RFP	+35.128 RMW	-1.985 EIN	+.3929 RPP_{-1}	-.1011 D1	-1.8204 D2	-.4865 D3	47	.952	—	-1.43	1.652
	(-.56)	(2.91)	(1.92)	(-1.72)	(2.88)	(-.09)	(-2.11)	(-.53)					

[1]Numbers in parentheses are coefficients divided by respective asymptotic standard errors.
[2]Standard error of the regression.

TABLE 4. TIME REQUIRED FOR WHOLESALE PRICES TO ADJUST TO CHANGES IN THE FARM PRICE, FIVE U.S. CATFISH PROCESSING PLANTS, BASED ON 1980-83 DATA

Plant	Estimated coefficient of the lagged dependent variable[1] (b_4)	Implied adjustment interval $(b_4)^N = .05$[2]
		Months
A	.5326	4.8
B	.7592	10.9
C	.4774	4.1
D	.2258	2.0
E	.3929	3.2
A-E[3]	.4213	5.5

[1]Coefficient values are obtained from table 3.
[2]In the formula, .05 denotes 95 percent adjustment to the new equilibrium value and N is the number of periods (in this case months) required to accomplish that degree of price adjustment.
[3]Computed as a weighted average of plant-specific values with plant market shares serving as weights.

as indicated in table 4, changes in the farm price of fish require between 2 and 11 months to be fully reflected by a change in the wholesale price. The average lag for all plants is 6 months.[8]

Estimated coefficients of the binary variables suggest that most plants experience seasonal shifts in demand, peaking in the first quarter and gradually diminishing thereafter. Curiously, the estimated markup equations suggest that processors react to seasonal shifts in demand by *lowering* prices during peak demand periods. However, a more correct interpretation of the seasonal coefficients of the markup equation may be that they reflect seasonal changes in product mix. In particular, sales of the fresh product, which are priced lower than the frozen product, tend to peak in the first or second calendar quarter.

Consumer income has an unclear effect on catfish demand. Estimated coefficients are significant at the 5 percent level or lower only for two plants, A and B. For these two plants, the estimated income effect is negative, consistent with other studies *(9,3)*. The negative income effect reflects an image problem acknowledged by the industry: catfish is often viewed

[8]The large differences in the estimated lag may be related to plant size and, by inference, to market power. Note from table 4 that Plant B with less than 10 percent market share (see table 1) has an 11-month lag. By contrast, plants D and E, each with market shares of about 25 percent, have lags of 2-3 months. Plants A and C, with market shares of about 16 percent, have lags of 4-5 months. These results suggest some type of price leadership behavior, a notion that is consistent with an imperfectly competitive market.

as a low income food commodity. Possible industry 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 in the industry, plants D and E probably spend more for advertising and promotion to differentiate their products from rivals. Moreover, the data indicate these two plants have a greater proportion of sales consisting of value-added products (see "further processed" column, table 1). To the extent that the income coefficients for plants D and E represent the relative appeal to higher income groups of the more highly processed product forms, the inference can be made that these product forms hold the most promise for demand growth.

The hypothesis that imports undermine the industry is generally not supported by the econometric results. The coefficient of the import variable generally is not significant. Due to limited markets in which imports compete and their decreasing market share, from 14.9 percent of industry volume in 1980 to 4.2 percent in 1983 *(22)*, this finding is not surprising.

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

Price Elasticities

Demand and (long run) price transmission elasticities corresponding to the coefficients provided in table 3, evaluated at mean data points, are provided in table 5. These elasticities

TABLE 5. DEMAND AND PRICE TRANSMISSION ELASTICITIES FOR CATFISH, FIVE U.S. PROCESSING PLANTS, BASED ON 1980-83 DATA

Plant	Processor-level demand elasticities[1]	Farm-plant price transmission elasticities[1]	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[2]	–1.28	.29	–.37

[1]Evaluated at mean data points.
[2]Computed as a weighted average of preceding elasticities with plant market shares serving as weights.

are calculated from reduced-form coefficients and therefore represent "total elasticities" (see Appendix B). The processor-level demand elasticities range from −.44 to −1.59 but tend to cluster around −1.5, indicating that the demand curve faced by processors is price elastic. This finding is consistent with an earlier study showing catfish demand at retail to be price elastic with an estimated elasticity coefficient of about −2.5 *(19)*. Kinnucan *(12)* estimated the demand elasticity at wholesale to range from −.85 to −2.37, depending on the point of evaluation along the demand curve, but the elasticity at data means was estimated to be −1.54.

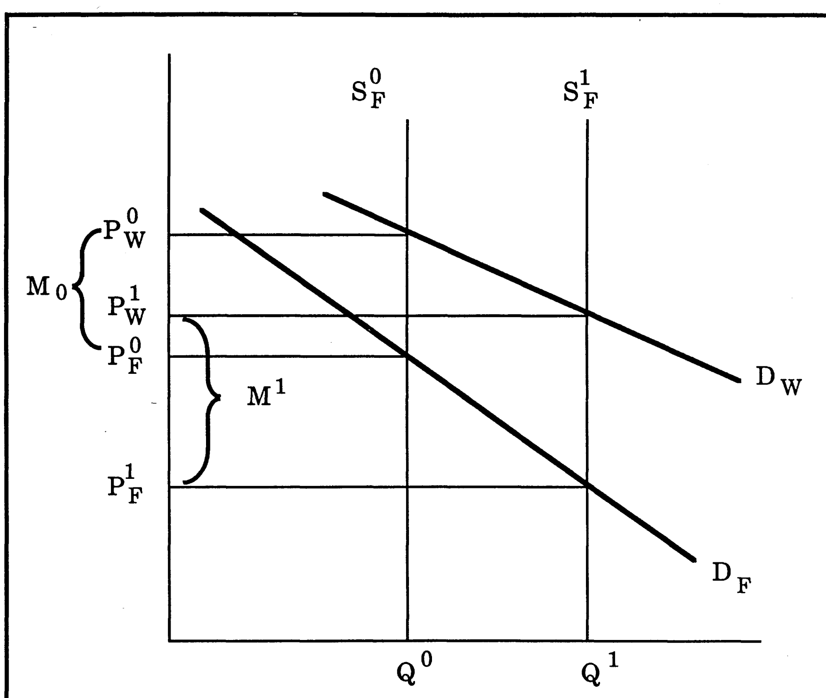
Transmission elasticities showing the linkage between farm and FOB processor prices range from .09 for plant B to .44 for plant D. The wider variation across plants in transmission vis-a-vis demand elasticities is consistent with the price-setting hypothesis stated earlier. The ability to exercise control over output prices permits firms to deploy different 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 for catfish because demand elasticities across plants are similar, table 5.

A parameter pivotal in determining the economic implications of technical change and other forces affecting the industry 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 *(7*, pp. 404-405). The farm-level elasticities so derived range from −.08 for plant A to −.69 for plant D, indicating an inelastic demand at the farm level, table 5. Weighting the plant-specific estimates by respective (sample) market shares and summing yields an aggregate farm-level demand elasticity of −.37. This estimate is below the lower bound estimate (−.65) given in Raulerson and Trotter *(19)*, 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. Specialized processing means that no substitutes exist for live catfish at the plant level. This fact, coupled with a processing-level demand elasticity that just exceeds unity, makes it plausible that the demand curve faced by catfish producers is inelastic even though demand at the plant level is elastic.

IMPLICATIONS

Demand being price elastic at the wholesale level but price inelastic at the farm level has several implications. First, prices at the farm level will be more volatile than prices at the wholesale level, as shown in the figure below. The curves D_W and D_F indicate the initial level of wholesale and farm-level demand. (The D_W curve is less steep than the D_F curve to reflect the more elastic demand at the wholesale level.) The initial level of supply is $S_F{}^o$, resulting in wholesale and farm-level prices of $P_W{}^o$ and $P_F{}^o$, respectively.

Now consider the effect of an increase in supply from $S_F{}^o$ to $S_F{}^1$. The wholesale price declines moderately to $P_W{}^1$, but farm price drops sharply to $P_F{}^1$. Reversing the process, if supply decreases from $S_F{}^1$ to $S_F{}^o$, the farm price responds



Impacts of supply shifts on farm and wholesale prices, marketing margins, and revenue when demand elasticities at the two levels differ.

strongly (increasing from P_F^1 to P_F^o) while the wholesale price responds only moderately (increasing from P_W^1 to P_W^o). Thus, weather, disease, off-flavor *(16)*, or technology-related shifts in supply will have a relatively greater impact on farm prices than on wholesale prices due to less elastic demand at the farm level.

The differing elasticities at farm and wholesale will affect the farm-wholesale marketing margin, causing the margin to widen when supply increases and to narrow when supply decreases. The phenomenon, too, is illustrated by the diagram. When supply is at the S_F^o level, the marketing margin is $P_W^o - P_F^o = M^o$, assuming farm and wholesale quantities are measured in similar units, e.g., wholesale quantity is expressed in liveweight equivalent. An increase in supply to S_F^1 increases the margin to $P_W^1 - P_F^1 = M^1$. Because the margin represents funds available to defray labor, capital, and other input costs, increases in farm supply are beneficial to the processor. Thus, an incentive exists for the processor to encourage new technology and other improvements that would increase the farm supply of catfish.

Finally, the effect of changes in supply on processor revenues will differ from the effect on farm revenues. This is best understood by recalling that the relationship between price (quantity) and industry revenue is governed by the price elasticity of demand: a price decrease (caused by an increase in supply) will decrease industry revenue only if demand is price inelastic. If demand is price elastic, however, a price decrease actually increases industry revenue.

Applying the principle that the correlation between price (quantity) and revenue depends on the demand elasticity to the catfish industry, it is apparent that an increase in supply (reduction in price) will cause revenues received by processors to increase but revenues received by producers to decrease. Since revenues received by producers represent expenditures by processors, profit margins of processors are expected to widen as supply increases, at least in the short run. By the same token, decreases in supply benefit producers but not processors, in that the revenues increase for producers but decrease for processors. Thus, as concluded earlier, processors have a stake in ensuring steady growth in technical efficiency of catfish production.

The foregoing results have implications for the off-flavor problem. With an inelastic farm-level demand, the increased farm marketings that would follow elimination or effective control of off-flavor would reduce total revenues received by catfish producers.[9] Thus, the procurement cost of processors would decrease. The reduced cost of live fish, coupled with economies of size realized from higher volume processing *(6)*, suggests 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 more than proportional increases in retail sales (because of an elastic demand). Expanded volume would permit the operation of more efficient-sized plants capable of capturing the scale economies that appear to be important in catfish processing *(6)*.

SUMMARY AND CONCLUSIONS

A three-equation demand system based on a price setting behavioral hypothesis was used to estimate demand elasticities for catfish at wholesale and farm levels of the market. Results, based on disaggregated processing plant data, suggest that demand is price elastic ($E_D = -1.28$) at the wholesale level but price inelastic ($E_D = -.37$) at the farm level. The differing elasticities at the two marketing stages imply: (1) greater price volatility at the farm vis-a-vis wholesale level, (2) wider farm-wholesale marketing margins when supplies of foodsize fish are plentiful than when supplies are tight, and (3) greater benefits to processors than to farmers of technical change that enhances the efficiency of catfish production.

Estimated farm-wholesale price transmission elasticities across plants range from .09 to .44 for a weighted average value of .29. That the transmission elasticities are smaller than one is consistent with the hypothesis that processing plants use a cost-plus pricing process to arrive at the selling price for processed fish. The widely differing transmission elasticities and lag structures may reflect the oligopsony character of catfish processing, an issue for further research.

A change in the farm price of catfish impels a change in the wholesale price, but not *pari passu*. Adjustments in the wholesale price lag changes in farm price 2 to 11 months, depending on the processing plant. The adjustment lag appears

[9]Though elimination of off-flavor would reduce farm revenues, farmers might still experience gains even in the short run if production costs fall sufficiently. See (15) for a more complete assessment of the off-flavor problem.

to be inversely related to plant size, with larger plants passing costs through more rapidly than smaller plants. Collectively, the wholesale price requires about 6 months to respond fully to a change in the farm price.

Further research on catfish demand could focus on retail level relationships, perhaps emphasizing differences between institutional (e.g., restaurant, fast-food) and home uses of catfish. Extension of the research reported in this bulletin might consider separate demands for the different product forms, fresh versus frozen or whole fish versus value-added or further processed fish.

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APPENDIX A: Computation of Total Elasticities

Two types of elasticities can be computed from a system of simultaneous equations: a partial (direct) elasticity and a total elasticity. The partial elasticity quantifies the relationship between two variables, holding constant all other variables in the model. It is calculated from the relevant structural equation. The total elasticity, by contrast, quantifies the relationship between two variables, permitting other variables in the model to adjust accordingly. Total elasticities are computed from the relevant reduced-form equation. Total elasticities are preferred to partial elasticities when the elasticities are to be used in forecasting *(1)* or welfare measurement *(11)*. Too, total elasticities provide an unambiguous interpretation of the relationship between elasticities and flexibilities obtained from simultaneous equation systems *(2)*.

Total elasticities that relate an endogenous variable to an exogenous variable can be computed in a straightforward manner from the relevant analytically derived, reduced-form equation. Total elasticities involving two endogenous variables, however, pose a complication. The problem is that, by definition, each reduced-form equation contains only one endogenous variable; hence, the required derivative for the elasticity involving two endogenous variables does not appear in the reduced-form equation. The solution to the problem, originally suggested by Buse *(1)* and elaborated by Chavas et al. *(2)*, is to manipulate the reduced form in a way that treats the endogenous variable of interest as "conditionally exogenous."

The two elasticities of interest in the model, the wholesale demand elasticity (E_D) and the farm-wholesale price transmission elasticity (E_T), are of the two types just described. That is, E_T relates an endogenous variable (RPP) to an exogenous variable (RFP) and therefore is easily computed directly from the relevant reduced-form equation. But E_D involves two variables that are each endogenous, QDN and RPP. To compute its elasticity, additional algebraic steps are required.

In the following, three things are done: (1) A general expression for the reduced form of the structural model is derived; (2) from the reduced form, a general expression for the total elasticity of price transmission is derived; and (3) the procedure of Chavas et al. *(2)* is applied to obtain a general expression for the total wholesale-level demand elasticity. It will be shown that for this particular simultaneous equation system, the partial and total elasticities of demand are identical but the two transmission elasticities differ.

Derivation of the Reduced Form

First, rearrange the model so that all endogenous variables appear to the left of the equal sign (ignore error terms):

(A.1) $QDN - a_1RPP = a_0 + a_2RYN + a_3MN + a_4D1 + a_5D2 + a_6D3$

(A.2) $RPP - b_3EIN = b_0 + b_1RFP + b_2RMW + b_4RPP_{-1} + b_5D1 + b_6D2 + b_7D3$

(A.3) $EIN + QDN = QHN + EIN_{-1}$

In matrix form, the above system can be written as:

(A.4) $AY = BX$;

where A is a matrix of coefficients of the endogenous variables;

$$A = \begin{bmatrix} 1 & -a_1 & 0 \\ 0 & 1 & -b_3 \\ 1 & 0 & 1 \end{bmatrix}$$

Y is a (column) vector of endogenous variables;

$$Y = \begin{bmatrix} QDN \\ RPP \\ EIN \end{bmatrix}$$

B is a matrix of coefficients of the predetermined or exogenous variables;

$$B = \begin{bmatrix} a_0 & a_2 & a_3 & 0 & 0 & 0 & 0 & 0 & a_4 & a_5 & a_6 \\ b_0 & 0 & 0 & b_1 & b_2 & b_4 & 0 & 0 & b_5 & b_6 & b_7 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \end{bmatrix}$$

and X is a (column) vector of exogenous or predetermined variables;

$$X = \begin{bmatrix} 1 \\ RYN \\ MN \\ RFP \\ RMW \\ RPP_{-1} \\ QHN \\ EIN_{-1} \\ D1 \\ D2 \\ D3 \end{bmatrix}$$

The reduced form of the system is found by solving the structural equations for the endogenous variables. With matrix algebra, this is done by premultiplying both sides of equation (A.4) by A^{-1}, yielding:

$$\text{(A.5)}\ Y = A^{-1} BX.$$

Since A is a small (3x3) dimension matrix involving several zeros and ones, it is easy to verify that its inverse is:

$$A^{-1} = \frac{1}{1 + a_1 b_3} \begin{bmatrix} 1 & a_1 & a_1 b_3 \\ -b_3 & 1 & b_3 \\ -1 & -a_1 & 1 \end{bmatrix}$$

Letting C^T represent the transpose of the matrix of reduced-form coefficients and applying equation (A.5), a general expression for the reduced form is:

$$C^T = \lambda \begin{array}{c} \begin{array}{ccc} \underline{QDN} & \underline{RPP} & \underline{EIN} \end{array} \\ \begin{bmatrix} a_0 + a_1 b_0 & b_0 - a_0 b_3 & -a_0 - a_1 b_0 \\ a_2 & -a_2 b_3 & -a_2 \\ a_3 & -a_3 b_3 & -a_3 \\ a_1 b_1 & b_1 & -a_1 b_1 \\ a_1 b_2 & b_2 & -a_1 b_2 \\ a_1 b_4 & b_4 & -a_1 b_4 \\ a_1 b_3 & b_3 & 1 \\ a_1 b_3 & b_3 & 1 \\ a_4 + a_1 b_5 & b_5 - a_4 b_3 & -a_4 - a_1 b_5 \\ a_5 + a_1 b_6 & b_6 - a_5 b_3 & -a_5 - a_1 b_6 \\ a_6 + a_1 b_7 & b_7 - a_6 b_3 & -a_6 - a_1 b_7 \end{bmatrix} \end{array} \begin{array}{c} 1 \\ RYN \\ MN \\ RFP \\ RMW \\ RPP_{-1} \\ QHN \\ EIN_{-1} \\ D1 \\ D2 \\ D3 \end{array}$$

where $\lambda = \dfrac{1}{1 + a_1 b_3}$.

Price Transmission Elasticity

The general expression for the (long run) price transmission elasticity is:

$$\text{(A.6)}\ E_T = \frac{\partial\, RPP}{\partial\, RFP} \bullet \frac{1}{1 - K} \frac{RFP^*}{RPP^*}$$

where K = coefficient of the lagged dependent variable, RFP* = mean farm price; and RPP* = mean processor price.

From the matrix of reduced-form coefficients, we have,

$$\frac{\partial\, RPP}{\partial\, RFP} = \frac{b_1}{1 + a_1 b_3} \text{ and } K = \frac{b_4}{1 + a_1 b_3}$$

Substituting these expressions into equation (A.6) and simplifying yields:

$$(A.7)\quad E_T = \frac{b_1}{1 + a_1 b_3 - b_4} \frac{RFP^*}{RPP^*}$$

Equation (A.7) is the general expression for the total (long run) price transmission elasticity. By contrast, the partial (long run) advertising elasticity is:

$$(A.8)\quad E_T' = \frac{b_1}{1 - b_4} \frac{RFP^*}{RPP^*}$$

Comparing equations (A.7) and (A.8), it is apparent that the total transmission elasticity differs from the partial transmission elasticity in that the former takes into account, via the coefficients a_1 and b_3, how processor inventories (EIN) and sales (QDN) are affected by a change in the farm price. Since a_1 and b_3 are both expected to have negative signs, b_1 is positive, and $1\text{-}b_4$ is expected to be a positive fraction, the total elasticity is smaller than the partial elasticity. Apparently, permitting inventories and sales to adjust to changes in farm price shrinks the value of the farm-wholesale price transmission elasticity. The magnitude of the differences between the partial and total elasticities are indicated in the following table. (These elasticities are computed from coefficients presented in table 3 and means of table 1 of the text.)

		E_T	E_T'
Plant	A	.18	.19
	B	.09	.12
	C	.41	.44
	D	.44	.50
	E	.19	.24

Wholesale Demand Elasticity

The wholesale demand elasticity is defined as:

$$(A.9)\quad E_P = \frac{\partial QDN}{\partial RPP} \frac{RPP^*}{QDN^*}$$

where RPP* and QDN* are mean values, respectively, for wholesale price and processor sales. Because QDN and RPP are both endogenous, this elasticity cannot be computed from the reduced form.

According to Chavas et al. *(2)*, the total elasticity corresponding to equation (A.9) can be computed if the system is appropriately manipulated so that RPP can be regarded as conditionally exogenous. This involves solving the system so that the remaining endogenous variables, i.e., those not part of the elasticity in question, are permitted to adjust to their new equilibria as RPP changes.

In the model, there is only one remaining endogenous variable, EIN. The Chavas et al. *(2)* technique amounts to solving for EIN in terms of exogenous variables and QDN and RPP. This can be accomplished by rewriting equation (A.3) as:

$$(A.3') \; EIN = QHN + EIN_{-1} - QDN.$$

Then substitute EIN into equation (A.1) and (A.2) wherever EIN appears. Since EIN does not appear in the demand equation, equation (A.1), the total elasticity is simply

$$E_D = \frac{\partial QDN}{\partial RPP} \frac{RPP^*}{QDN^*} = a_1 \frac{RPP^*}{QDN^*}$$

which is identical to the partial elasticity computed directly from the structural equation. The numerical values for E_D for each plant based on the estimated values of a_1 and data means are presented in table 5 of the text.

APPENDIX B: Reduced-Form Coefficients

The general expression for the reduced form derived in Appendix A was applied to the structural parameter estimates presented in table 3 of the text to construct a matrix of reduced-form coefficients for each plant. These are presented in appendix tables 1-5. Appendix table 6 is the weighted average of plant-specific reduced-form coefficients, where the (sample) market share of each plant was used as the weighting factor. As such, the numbers in appendix table 6 can be interpreted as a set of reduced-form coefficients applicable to the entire industry. These coefficients can be used to simulate the effect of changes in predetermined variables, e.g., wage rates or consumer income, on the demand for catfish, processor price, and processor inventories.

APPENDIX TABLE 1. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, PLANT A

Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	33.90488	35.11212	-35.43062
RYN	0.02434	0.04992	-0.02434
MN	-8.07282	-16.55574	8.07282
RFP	-0.00465	0.21955	0.00465
RMW	-1.05817	49.91390	1.05817
RPP_{T-1}	-0.01082	0.51041	0.01082
QHN	0.04167	-1.96535	0.95833
EIN_{T-1}	0.04167	-1.96535	0.95833
D_1	0.94585	-0.26664	-0.94585
D_2	0.40506	-0.17270	-0.40506
D_3	0.29637	0.60999	-0.29637

APPENDIX TABLE 2. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, PLANT B

Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	15.80047	0.79360	-17.25057
RYN	-0.07159	-0.07631	0.07159
MN	-3.25652	-3.47145	3.25652
RFP	-0.00313	0.07264	0.00313
RMW	-1.08737	25.22911	1.08737
RPP_{T-1}	-0.03136	0.72757	0.03136
QHN	0.04403	-1.02158	0.95833
EIN_{T-1}	0.04403	-1.02158	0.95833
D_1	0.83761	-0.94274	-0.83761
D_2	0.43221	-1.14626	-0.43221
D_3	0.27952	-0.34334	-0.27952

APPENDIX TABLE 3. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, PLANT C

Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	15.67339	-18.46215	-20.08783
RYN	-0.04820	-0.02873	0.04820
MN	-2.83226	-1.68803	2.83226
RFP	-0.04563	0.60203	0.04563
RMW	-3.03853	40.08617	3.03853
RPP_{T-1}	-0.03468	0.45751	0.03468
QHN	0.04329	-0.57117	0.95833
EIN_{T-1}	0.04329	-0.57117	0.95833
D_1	1.02281	-0.84237	-1.02281
D_2	0.66335	-0.42778	-0.66335
D_3	0.53042	-0.45803	-0.53042

APPENDIX TABLE 4. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, PLANT D

Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	-42.76368	-49.72699	36.82600
RYN	-0.30628	-0.21951	0.30628
MN	7.61301	5.45624	-7.61301
RFP	-0.12923	0.92307	0.12923
RMW	-5.05541	36.11005	5.05541
RPP_{T-1}	-0.03029	0.21639	0.03029
QHN	0.09616	-0.68684	0.95833
EIN_{T-1}	0.09616	-0.68684	0.95833
D_1	0.24475	-0.78713	-0.24475
D_2	0.12810	-0.66721	-0.12810
D_3	0.14461	0.39594	-0.14461

APPENDIX TABLE 5. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, PLANT E

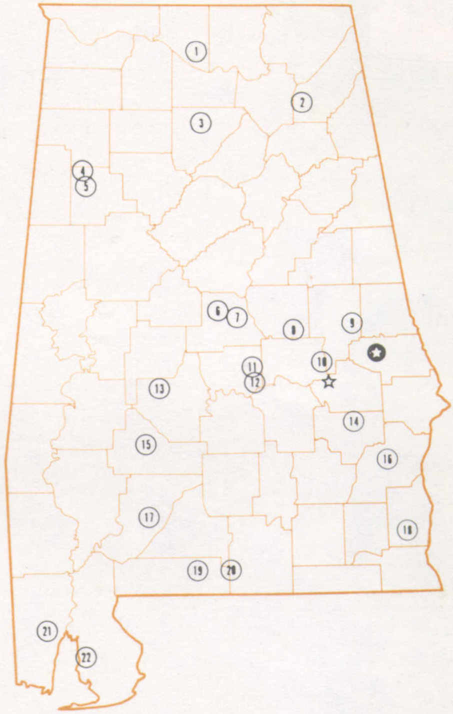
Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	-2.55336	3.00743	4.52107
RYN	0.03910	0.07683	-0.03910
MN	3.16155	6.21244	-3.16155
RFP	-0.03459	0.35008	0.03459
RMW	-3.32604	33.66438	3.32604
RPP_{T-1}	-0.03720	0.37653	0.03720
QHN	0.18605	-1.88313	0.95833
EIN_{T-1}	0.18605	-1.88313	0.95833
D_1	1.22359	2.28866	-1.22359
D_2	1.13798	0.15289	-1.13798
D_3	0.68690	0.79302	-0.68690

APPENDIX TABLE 6. ANALYTICALLY DERIVED REDUCED-FORM COEFFICIENTS OF THE STRUCTURAL MODEL, WEIGHTED AVERAGE OF FIVE PLANTS

Exogenous variable	Endogenous variables		
	QDN	RPP	EIN
1	–2.74625	–10.52507	0.42138
RYN	–0.08767	–0.04560	0.08767
MN	0.83080	–0.19517	–0.83080
RFP	–0.05511	0.50663	0.05511
RMW	–3.15774	37.36469	3.15774
RPP_{T-1}	–0.02978	0.40341	0.02978
QHN	0.09689	–1.24047	0.95833
EIN_{T-1}	0.09689	–1.24047	0.95833
D_1	0.82560	0.11149	–0.82560
D_2	0.57424	–0.36731	–0.57424
D_3	0.39914	0.31494	–0.39914

Alabama's Agricultural Experiment Station System
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

⍟ Main Agricultural Experiment Station, Auburn.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Foundation Seed Stocks Farm, Thorsby.
7. Chilton Area Horticulture Substation, Clanton.
8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
10. Plant Breeding Unit, Tallassee.
11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. The Turnipseed-Ikenberry Place, Union Springs.
15. Lower Coastal Plain Substation, Camden.
16. Forestry Unit, Barbour County.
17. Monroeville Experiment Field, Monroeville.
18. Wiregrass Substation, Headland.
19. Brewton Experiment Field, Brewton.
20. Solon Dixon Forestry Education Center, Covington and Escambia counties.
21. Ornamental Horticulture Field Station, Spring Hill.
22. Gulf Coast Substation, Fairhope.