CATFISH PRODUCER HARVEST RESPONSE TO PRODUCTION AND ASYMMETRIC PRICE RISK

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Abstract

Harvest response to production and asymmetric price risk was analyzed using an ordinary least squares model. Statistically significant responses to production-quality and output price risk were indicated. Results suggest that alternative pricing strategies designed to reduce risk may alter harvest response and decrease month to month harvest variability.

Key words: catfish, harvest, risk

Studies of aggregate producer supply response to risk (Behrman; Just; Lin; Traill; Winter and Whittaker; Hurt and Garcia; Brorsen et al; Tronstad and McNeill) have attempted to determine the degree to which production and price risk influence producer decisions prior to the beginning of the production process. Models resulting from these studies have then been used to evaluate the implications of farm programs in reducing risk and altering supply response.

Total short-run supply response over the production cycle is often relatively inelastic after initial production decisions have been made and implemented. However, producers may be able to change the timing of harvest and delivery of a storable or semi-storable commodity. Changes in perceived risk factors from those that existed prior to the beginning of the production process can affect the producers' harvest pattern thus altering the very short-run supply of a commodity and its associated price.

The objectives of this paper were to (1) evaluate sources and influences of production and price risk on the harvesting decisions made by United States catfish producers; (2) determine the impact of the omission of risk factors on estimated harvest responsiveness with respect to output price and input cost; and (3) evaluate the implications of alternative input and output pricing strategies on harvesting decisions made by catfish producers.

A theoretical non-risk model was hypothesized to explain the monthly harvest of food-size catfish. After initial estimation, risk variables were incorporated into the model to account for production, input price, and output price risk. Individual risk variables rather than an aggregate risk variable (i.e. deviations in returns or profits) were used so that specific influences of risk could be isolated.

A brief description of the catfish industry is followed by a description of the hypothesized harvest response model. Data, estimation results, and an analysis of harvest response to alternative input and output pricing strategies are presented in section three. The final section contains conclusions and suggestions for extension of the analysis.

U.S. CATFISH INDUSTRY

Aquacultural production of channel catfish *(Ictalurus punctatus)* has existed in the United States for over fifty years. However, it has been only in the last ten years that the industry has evolved from a primarily import-based industry to a domestic-production based industry. Production is centered in the Delta region of Mississippi where over 75 percent of the marketable food-size fish are produced annually. The industry is characterized by a competitive production sector where producers raise or purchase four- to six-inch fingerlings to stock and grow out in earthen ponds. The grow-out period lasts six to seven months with the principal season being from the first of April to September or October, though production does take place year round. Two peak harvesting periods exist. The first occurs at the end of the principal production season in September or October. The second takes place in late winter prior to the Lenten period and spring restocking.

The input supply and processing sectors are characterized by a few large firms that supply the main input to production (feed, accounting for 35 to 50 percent of production costs) and handle 80 percent of the food-size fish marketed by producers. Both

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feed manufacturing and processing firms are either farmer-owned cooperatives or privately-held corporations. A fairly homogeneous resource base, input supply system, and well-controlled marketing system exist for the Delta producers.

Major sources of risk to producers are production, input price, and output price. A principal element of production risk is the occurrence in fish of a condition known as off-flavor whereby fish pick up distasteful flavors from their pond environment and become unmarketable. Algae growth in ponds is believed to be one of the leading causes of off-flavor, but to date, the exact causes and solutions are unknown. To clear off-flavor, the fish are moved to cleaner ponds, or the algae growth is controlled in existing ponds. However, it can take from several days to several months for the off-flavor to clear. During this time the fish must be maintained. Maintenance costs include both physical and opportunity costs. Physical costs of maintaining fish in the pond are related to water temperatures and oxygen content which affect the amount of feed and aeration required. Opportunity costs are related to the market price for fish, physical maintenance costs, and interest rates.[1]

Input price risk is due predominately to unexpected upward changes in the price producers pay for feed and to a lesser extent to unexpected changes in the price paid for fingerlings. Output price risk is due to unexpected downward changes in the price received by producers for food-size fish. "Unexpected" in both cases means that price movements differ from those anticipated by producers.

It was hypothesized that production, input price, and output price risk increase instability in the quantity of fish available for processing. In turn, the quantity of processed fish available to the consuming public becomes more unstable, possibly decreasing demand.

Catfish producers formed the Catfish Bargaining Association (CBA) in late 1989 in response to falling producer prices within the industry. The CBA will set the pond price for marketable fish in an attempt to stabilize prices and increase producer revenue to stimulate production expansion. A contract agreement with a majority of the catfish industry processors has been ratified and will run through mid-1991, at which time it may be renewed.

A harvest model was used to evaluate the implications of alternative pricing strategies on harvesting decisions made by catfish producers. Specifically, a comparison of price pooling strategies in the input sector in conjunction with various set price levels in the live-fish marketing sector will be made. These comparisons will give an indication as to the effectiveness of the CBA's pricing strategy.

HYPOTHESIZED MODEL

The aggregate harvest equation including risk variables was specified as:

LIVWTS = f(S6, C6, FARMP(-6), FEEDP(-6), SHIFT, YRISK, IPRISK, OPRISK)

where:

LIVWTS = Monthly total live-weight of food-size fish harvested and processed, millions of pounds.

S6, C6 = Sine and cosine variables, respectively, with six month periods.

FARMP(-6) = Average monthly price paid to farmers for food-size fish, lagged six months, dollars per pound.

FEEDP(-6) = A weighted average of the average monthly price received by farmers per pound for corn and the average monthly wholesale prices per pound for high protein soybean meal and 67 percent protein East Coast fishmeal, the major components of commercial catfish feed, lagged six months. The weights (0.3, 0.48, and 0.1 for corn, soybean meal, and fishmeal, respectively) are based on an average of the compositions of several "practical" commercial feeds (Dupree and Huner).

SHIFT = Dummy variable indicating a major increase in the pond acreage used in the production of catfish, zero for Jan. 1984 through Feb. 1987, one for Mar. 1987 through Oct. 1990.

YRISK = Seasonality measure of the probability of production-quality problems due to the occurrence of off-flavor.

IPRISK = Square of a weighted average of past feed prices minus the current price of feed if the difference is negative, zero otherwise.

[1] Producers incur two forms of opportunity cost due to their inability to harvest and market fish: (1) returns that could have been earned on funds invested in the maintenance of off-flavor fish, and (2) returns that could have been earned on the receipts from the sale of marketable fish. Interest rates represent a level of return that could have been earned in both cases.

OPRISK = Square of a weighted average of past output prices minus the current price of fish if the difference is positive, zero otherwise.

Means and standard deviations for the data used in the analysis are presented in Table 1. Hypothesized signs of the effects of each variable on producer harvest are discussed below.

S6 and C6 are sine and cosine variables used to represent the harvest cycle variation (Franzmann and Walker) that exists in the production of food-size fish. January 1984 is time zero for the two variables and at time zero, S6 and C6 equal zero and one, respectively. The two variables and their estimated coefficients can be transformed by means of a trigonometric identity[2] (Newton) to form a single cosine variable that indicates the estimated harvest peaks and troughs associated with the production of food-size fish.

FARMP(-6) and FEEDP(-6) reflect producer future output and input price expectations at the beginning of the production process. The coefficients for the variables are hypothesized to have positive and negative signs respectively. Producers are encouraged to increase their production intensity as the price they expect to receive for marketable fish increases. Such increases in intensity may be in the form of increased stocking rates or continued production in ponds that may be scheduled for renovation or otherwise removed from production. These changes in production intensity in turn affect the level and timing of fish available for harvest at the end of the production cycle. The expected price of feed at the beginning of the production cycle is hypothesized to be negatively related to the intensity of production and ultimately the harvest level.

The SHIFT variable was used to indicate a rapid increase in the pond acreage used in the production of catfish during the late 1980s. This increase in production in turn increased the level of marketable fish available for harvest. The coefficient for the variable is expected to be positive.

YRISK is a proxy to represent the probability of production-quality problems due to the occurrence of off-flavor. The variable is roughly based on data from Keenum and Waldrop.[3] Occurrence of off-flavor in food-size fish may be a function of the time of year at which a producer attempts to harvest and market. Generally off-flavor problems are low at the beginning of the year and increase throughout the spring, summer, and early fall. As winter approaches the problem tends to decrease.[4] As the probability of off-flavor (YRISK) increases, the available supply of harvestable food-size fish was expected to decrease due to quality constraints imposed by processors.

Input price risk (IPRISK) is an asymmetric measure of the producers' perceived risk associated with continuing to hold fish in pond inventory in light of an increase in the current price of fish feed relative to an expected feed price. Expected feed prices are represented by a weighted average of feed prices from the immediate past. If the current price of feed is below the weighted average of past prices, there is assumed to be no price risk and IPRISK is zero. If the current price of feed is above a weighted

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[2]The identity is: $a\cos(x) + b\sin(x) = \sqrt{(a^2 + b^2)}\cos(x - \theta)$
where:

$$\theta = \begin{cases} \arctan(b/a) & , a > 0 \\ \arctan(b/a) + \mathrm{sgn}(b)\pi & , a < 0 \\ \mathrm{sgn}(b)\pi/2 & , a = 0 \end{cases}$$

and

$$\mathrm{sgn}(b) = \begin{cases} 1 & , b \geq 0 \\ -1 & , b < 0 \end{cases}$$

$\sqrt{(a^2 + b^2)}$ is the amplitude of the harvest cycle variable and θ is the phase angle or horizontal shift of the harvest cycle variable.

[3]YRISK was established as follows: the quarterly levels of unmarketable fish were assumed to be the levels of unmarketable fish for the third month of each quarter for the first three quarters of the year. First and second month levels of unmarketable fish were assumed to equal one-third and two-thirds, respectively, of the third month's level of unmarketable fish. For the fourth quarter of the year, the quarterly level of unmarketable fish was assumed to be the level of unmarketable fish for the first month of the quarter. The second and third month levels of unmarketable fish were assumed to equal two-thirds and one-third, respectively, of the first month's level of unmarketable fish. This weighing scheme yields a negatively skewed distribution for unmarketable fish with its mode occurring in the month of September each year.

[4]Obviously the off-flavor problem is not a function of time *per se* but rather, is a function of the changes that occur over time. For example, as time progresses through the year, weather conditions change from generally cold weather to warm and hot weather and longer days. These changing conditions may allow the growth of algae that influences the flavor of fish, thus causing quality problems at the end of the summer and into early fall. As temperatures begin to cool and the days shorten with the approach of winter, the growth of the algae may decrease and the problems with flavor begin to decrease. Thus, time is simply used as an indicator of when the effects of off-flavor arise, not as a factor that actually causes the problem.

Table 1. Means and Standard Deviations of Variables Used in the Regression Equations

Variable	Mean	Standard Deviation
LIVWTS	21.758	6.401
S6	0.021	0.707
C6	0.000	0.716
FARMP(-6)	0.696	0.063
FEEDP(-6)	0.078	0.015
SHIFT[a]	0.537	N/A
YRISK	0.168	0.162
IPRISK	3.75E-5	1.27E-4
OPRISK	6.19E-4	1.13E-3

[a] Means of dummy variables indicate the percentage of observations with a value of one, and standard deviations are not applicable.

average of past prices, IPRISK is the square of that difference. Squaring the difference between the current price of feed and the weighted average of past prices implies that the level of producer perceived risk increases at an increasing rate as the difference increases. Thus, the level of producer perceived price risk is increasing at the margin rather than constant. Figures 1 and 2 present a comparison of the current price of fish feed, as represented by FEEDP, with a twelve month, arithmetically declining, weighted moving average of past feed prices and the resulting value of IPRISK, respectively. A twelve month weighted moving average was used to reflect a complete feed production cycle array of prices. The influence of IPRISK on the harvest of food-size fish was hypothesized to be positive. Holding fish in ponds as inventory becomes more expensive as the price of feed (and its associated risk) increases above expectations thus, inventories are reduced and harvest increases.

As with IPRISK, output price risk (OPRISK) is an asymmetric measure of the extent to which the current price paid for food-size fish varies from the producers' expected price as represented by a weighted average of prices from the immediate past. If the current price of fish is above a weighted average of past prices, there is assumed to be no price risk and OPRISK is zero. If the current price of fish is below a weighted average of past prices,

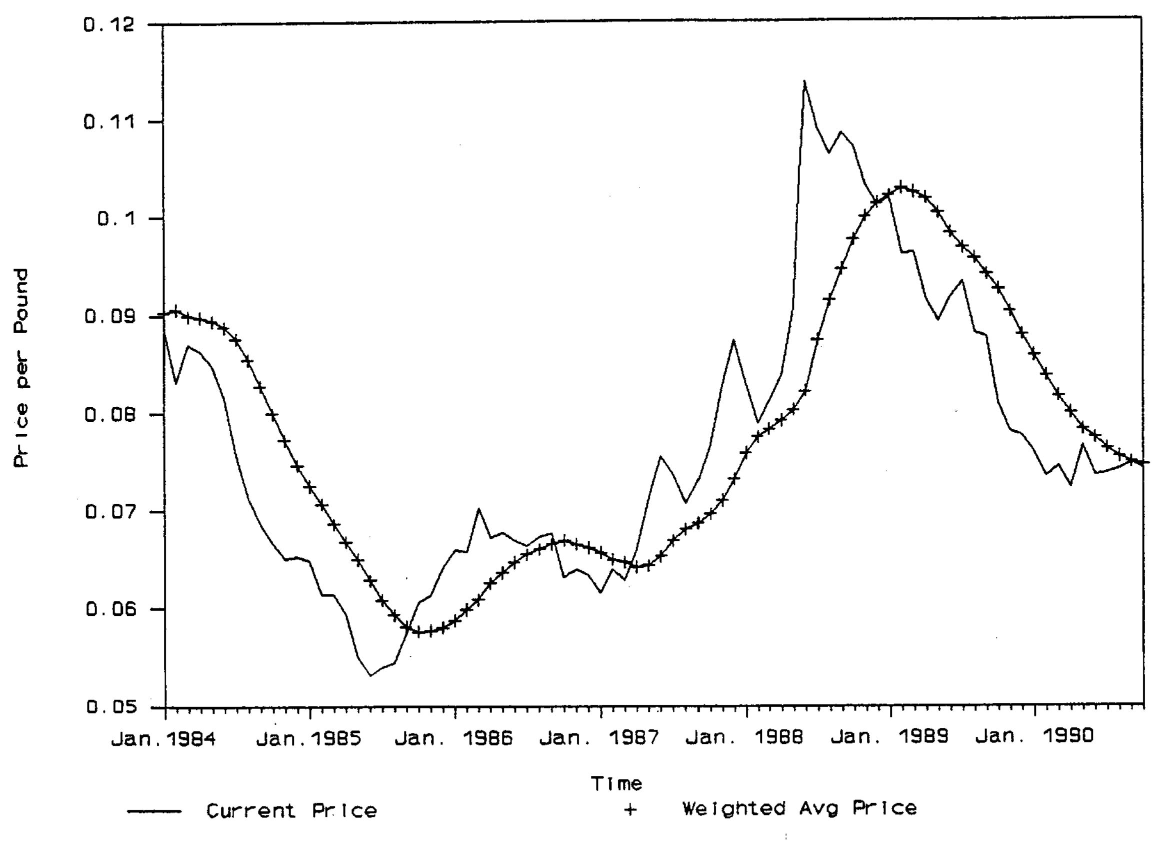

Figure 1. Input Price—Feed

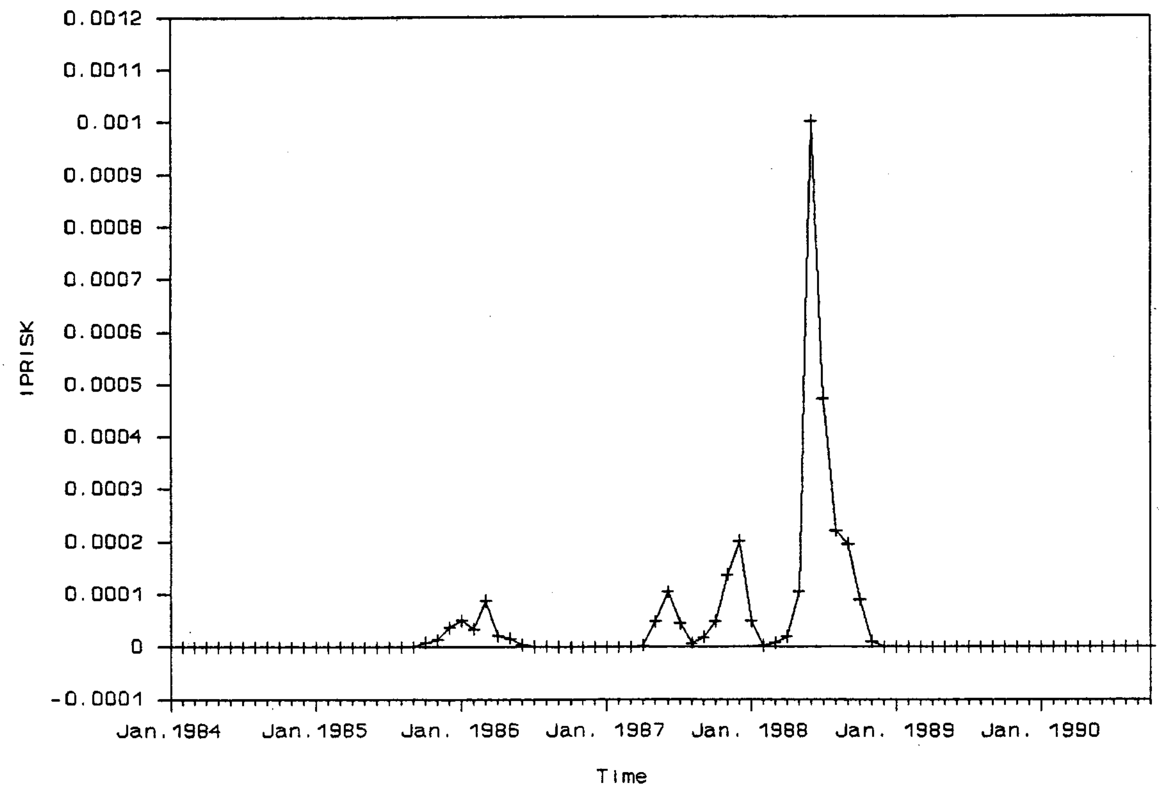

Figure 2. Input Price Risk—Feed

OPRISK is the square of that difference. A six month, arithmetically declining, weighted moving average of past fish prices was used to reflect a complete fish production cycle array of prices. Again, the influence of price risk on the harvesting of food-size fish was hypothesized to be positive. Holding fish in ponds as inventory becomes more expensive as the risk associated with fish prices increases, so producers harvest and market their fish.

The input and output price risk hypotheses appear to be contrary to those expressed in past aggregate supply risk research. Past research has attempted to model the influence of risk on producer choices as to production intensity at the beginning of the production process. Risk associated with input or output prices would cause the risk-averse producer to reduce the level of input use resulting in less production intensity and lower levels of supply. Thus, the hypothesized negative relationship between risk and aggregate supply. In this model, producer decisions at the end of the production process are being analyzed. Price risk arising at this point in time would influence the producers' decision to continue the current production process or to harvest and market. Adverse changes in either input or output prices would encourage the producer to harvest and market rather than hold fish as pond inventory, thus increasing the harvest.

Initial estimation indicated a highly significant, positively autocorrelated set of residual errors for both the non-risk and risk estimated equations. Moving average processes of degree one were incorporated into the models to account for the autocorrelated errors.

DATA AND ANALYSIS

The food-size catfish harvest equations were estimated using ordinary least squares and monthly data for the period Jan., 1984 to Oct., 1990. Data for the analysis came from the *Aquaculture Situation and Outlook Report,* and feed price data came from *Feed Situation and Outlook Report.*

The estimated coefficients for the non-risk and risk harvest equations are presented in Table 2. The signs of the estimated coefficients generally coincide with hypotheses and a high level of significance was achieved as indicated by the associated t-values. Overall, the equations fit the data well. F-tests for the null hypothesis that at least one of the non-intercept estimated coefficients is non-zero are highly significant for both the non-risk and risk equations.

For the non-risk equation, the hypothesized six month periodicity was significant and a 1.590 month shift in the cycle from January was indicated based upon the trigonometric identity outlined above. This result implies that the highest volumes of food-size fish harvested for processing exist in mid-February and mid-August, while the lowest volumes occur in mid-May and mid-November. The signs on the pre-production price coefficients are as expected, while only the output price coefficient (FARMP(-6)) is significantly different from zero. The dummy variable accounting for a shift in the pond acreage used in catfish production (SHIFT) is positive and significant.

When the risk variables are included, the hypothesized six month periodicity is again significant. The coefficients on the periodic variables indicate a 1.589 month shift in the cycle from January. This result implies that peaks and troughs in harvest level indicated by the estimated risk equation occur slightly earlier in the same months as compared with the cyclical pattern implied by the non-risk equation. Figure 3 shows the relationship between the periodicities of the two estimated coefficients. For the risk model the production-quality variable (YRISK) was included to gain a prospective of the combined cyclical effects of the harvest cycle variation and the seasonal yield-quality variation. As stated, both estimated equations indicate approximately the same cyclical peaks and troughs in harvest variation throughout the year. However, inclusion of the production-quality risk variable alters the amplitude of the estimated harvest cycle, particularly during the second half of the year. The decrease in harvest during the early summer months was amplified with the inclusion of the production-quality variable and the increase in harvest following the principal production period was muted. This change in harvest cycle patterns indicates that production risk factors must be accounted for in order to gain a truer understanding of the magnitude of variability that exists in the monthly harvest of marketable food-size catfish.

The signs of the coefficients on the pre-production price variables are as hypothesized and both are significant. The sign on the coefficient of the SHIFT dummy variable is again as expected and highly significant.

The production risk variable (YRISK) yielded a significant negative estimated coefficient. These results indicate that the general timing of the occurrence of off-flavor has strongly impacted the harvesting decision of catfish producers. The estimated peak harvest cycle variation occurring in August each year and an assumed high level of off-flavor occurring in September implies that producers may be attempting to harvest their fish just prior to an anticipated period of high off-flavor occurrence each year.

Table 2. OLS Estimates of Non-risk and Risk Equation Coefficients (t-values are in parentheses)

Independent Variables/Statistics	Non-Risk	Risk
Constant	5.126 (1.692*)	8.320 (2.761*)
S6	1.813 (4.784*)	2.172 (5.438*)
C6	-0.171 (-0.455)	-0.203 (-0.554)
FARMP(-6)	18.747 (4.138*)	16.724 (3.673*)
FARMP(-6)	-31.348 (-1.542)	-46.473 (-2.331*)
SHIFT	11.190 (19.276*)	11.881 (20.316*)
YRISK		-7.205 (-3.588*)
IPRISK		-3,456.308 (-1.589)
OPRISK		565.472 (2.049*)
MA(1)	0.663 (5.696*)	0.613 (5.169*)
Summary Statistics		
Observations	82	82
R^2	0.869	0.884
S.E. of the Regression	2.410	2.309
Durbin-Watson	1.987	1.993
F-Statistic	82.767	61.187

*Statistically significant at α = 0.05 level.

The estimated coefficient for the input price risk variable (IPRISK) yielded a non-statistically significant negative sign, opposite of that hypothesized. Feed costs represent a major portion of the cost of producing fish and any changes in these costs can dramatically affect producer returns (Keenum and Waldrop; Branch and Tilley) and should influence producer harvesting decisions. One possible reason for the lack of significance of the IPRISK variable may be the relative lack of risk that can be associated with feed prices over the period of estimation. Feed prices had been stable or falling with the exception of a period of approximately 16 months during 1987

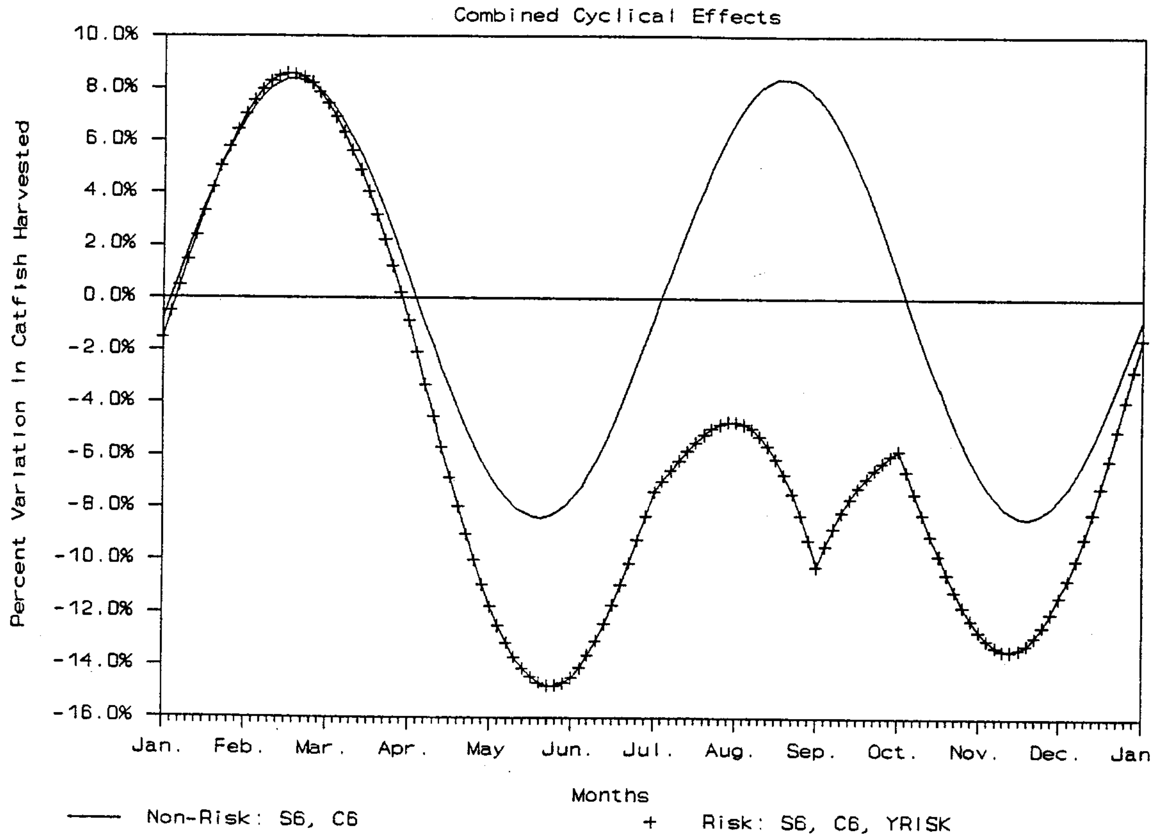

Figure 3. Harvest Periodicities: Combined Cyclical Effects

and early 1988. Periods of falling prices would not be considered risky to the fish producer based upon the asymmetric definition of price risk used and as such the general lack of input price risk over the estimation period may have contributed to the insignificance of the IPRISK variable.

The output price risk variable (OPRISK) yielded an expected positive sign that was significantly different from zero. These results suggest that producers can be encouraged to continue to hold fish if output prices are increasing or stable.

An F-test was conducted to check the significance of the risk variables in the harvest model (H_o: YRISK = IPRISK = OPRISK = 0). An estimated F-value of 3.234 was generated while $F_{3,72}$ is equal to 2.764 at the five percent level of significance. The null hypothesis was rejected and it was concluded that at least one of the risk variables has a significant effect on the level of fish harvest.

The implied elasticities of harvest response to pre-production output and input prices (FARMP(-6) and FEEDP(-6)) in the non-risk model are 0.600 and -0.112, respectively. For the risk model assuming a period of no risk (IPRISK and OPRISK equal zero), the implied elasticities are 0.535 and -0.166, respectively. The elasticities are 0.578 and -0.180, respectively, with the assumption of the occurrence of output and input price risk. These elasticities suggest that producer harvest may be more responsive to changes in input prices, particularly negative changes, than would be projected by a harvest model that did not account for the influences of producer perceived risk.

Input and output price risk can be affected by all parties associated with the production of food-size catfish. Spreading or contracting the sale of market-ready fish, holding fish in inventory reserves, spreading input purchases, contracting for feed purchases, maintaining some level of feed reserves, and organizing cooperative associations are a few of the options open to producers to control input and output price risk. Using futures markets to hedge anticipated feed ingredient prices, forward contracting, or pool pricing are all techniques available to feed manufacturers that may be used to reduce input price risk faced by the fish producer. Fish processors may reduce producer output price risk by contracting fish purchases.

An analysis of the impacts of price pooling strategies in the input sector and various set price levels in the live-fish marketing sector (as implemented by the CBA) was made using the estimated harvest risk equation. Under price pooling, a series of prices or costs were averaged in an attempt to lower the variability of the price passed on to patrons. Six and twelve month pooled prices were considered in the analysis. These pools reflect a complete array of prices over the feed production and fish production cycles, respectively. The analysis covers the same data period used in the model estimation, Jan. 1984 to Oct. 1990. Results of the analysis are presented in Table 3.

The actual average monthly harvest of catfish during the period of estimation was 21.758 million pounds of fish with a standard deviation of 6.401 million pounds. The harvest model estimates an average monthly harvest over the data period of 21.770 million pounds of fish with a standard deviation of 5.804 million pounds using the actual price data. Assuming that producers had paid a pooled price for feed based upon a twelve month moving average of past feed prices and had received the actual price for their output over the estimation period, then average monthly harvest would have risen slightly over the estimation period to 21.831 million pounds per month with a standard deviation of 5.882 million pounds. Alternatively, a six month moving average pooled price for feed and actual fish prices increased the average monthly harvest to 21.789 million pounds with a standard deviation of 5.832 million pounds. Assuming a set price (0.70 cents per pound) for fish over the analysis period and using actual feed prices yields an average monthly harvest of 21.485 million pounds with a standard deviation of 5.778 million pounds. Set prices of 0.75 and 0.80 cents per pound respectively and actual feed prices raise the monthly average harvest to 22.321 and 23.157 million pounds, respectively. The standard deviations of these harvest rates are unchanged from the 0.70 cents per pound level. Assuming a set price for fish and a six month moving average pooled price for feed yields an average monthly harvest of 21.505, 22.341 and 23.177 million pounds for 0.70, 0.75 and 0.80 cents per pound of fish, respectively. All the pricing schemes yield standard deviations of 5.832 million pounds. Assuming a set price for fish and a twelve month moving average pooled price for feed yields an average monthly harvest of 21.546, 22.382 and 23.219 million pounds for 0.70, 0.75 and 0.80 cents per pound of fish respectively. Again all the pricing schemes yield the same level of standard deviation, in this case, 5.881 million pounds.

These results indicated that a less variable level of monthly harvest is available by stabilizing prices paid to producers in the catfish industry and that price setting by the CBA in the live fish market may be a more effective way of increasing the level of fish harvested compared to a pool pricing scheme in the feed input market.

CONCLUSIONS

The results clearly suggest that the harvest of food-size catfish is significantly affected by falling output prices as these prices relate to producer output price risk and the increased occurrence of production-quality risk as defined by off-flavor. The hypothesis with respect to input price risk was rejected. Inclusion of risk variables decreased the magnitude of the estimated output price elasticity of harvest from 0.600 to 0.578. The input price supply elasticity was increased in magnitude by the inclusion of the risk variables from -0.112 to -0.180. Results from the pricing analysis suggest that decision makers within the catfish industry may want to consider alternative pricing strategies designed to reduce price risk in the system.

The principal conclusion is that risk is likely to be an important factor to consider when evaluating the harvest of catfish, and future research in this area

Table 3. Pricing Policy Analysis Under Risk Model Assumptions

	Average Monthly Harvest[a] (Standard Deviation of Average Monthly Harvest)			
Feed Price	Farm Price			
	Actual Prices	70 cents/lb	75 cents/lb	80 cents/lb
Actual Prices	21.770 (5.804)	21.485 (5.778)	22.321 (5.778)	23.157 (5.778)
6 mo. Avg Feed Prices	21.789 (5.832)	21.505 (5.832)	22.341 (5.832)	23.177 (5.832)
12 mo. Avg Feed Price	21.831 (5.882)	21.546 (5.881)	22.382 (5.881)	23.219 (5.881)

[a]Jan. 1984 to Oct. 1990, millions of pounds.

should include risk variables. Additionally, pricing techniques are available to reduce the risk associated with catfish harvesting, but a cooperative effort among input suppliers, processors, and producers will be needed for the success of these efforts.

REFERENCES

Behrman, J.R. *Supply Response in Underdeveloped Agriculture: ACase Study of Four Major Annual Crops in Thailand, 1937-63.* Amsterdam, the Netherlands: North-Holland Publishing Co., 1968.

Branch, William and Daniel S. Tilley. Oklahoma Net-Pen Catfish Production Systems: Estimated Production Levels and Costs. Agr. Exp. Sta., Division of Agr. Res. Rep. P-912, Oklahoma State University, Stillwater, OK, 1990.

Brorsen, B. Wade, Jean-Paul Chavas, and Warren R. Grant. "A Market Equilibrium Analysis of the Impact of Risk on the U.S. Rice Industry." *Am. J. Agr. Econ.,* 69.4 (1978) 733-739.

Dupree, Harry K. and Jay V. Huner, eds. *Third Report to the Fish Farmers—The Status of Warmwater Fish Farming and Progress in Fish Farming Research.* U.S. Department of the Interior, Fish and Wildlife Serv., 1984.

Franzmann, John R. and Rodney L. Walker. "Trend Models of Feeder,Slaughter, and Wholesale Beef Cattle Prices," *Am. J. Agr. Econ.,* 54.3 (1972): 507-512.

Hurt, Christopher A. and Philip Garcia. "The Impact of Price Risk on Sow Farrowings, 1967-78" *Am. J. Agr. Econ.,* 64.3 (1982):565-568.

Just, Richard E. "An Investigation of the Importance of Risk in Farmers' Decisions," *Am. J. Agr. Econ.,* 56.1 (1974): 14-25.

Keenum, Mark E. and John E. Waldrop. *Economic Analysis of Farm-Raised Catfish Production in Mississippi.* Miss. Agr. and For. Exp. Sta. Tech. Bull. 155, Mississippi State University, 1988.

Lin, William. "Measuring Aggregate Supply Response under Instability." *Am. J. Agr. Econ.,* 59.5 (1977):903-907.

MacDonald, Glenn M. and James G. MacKinnon. "Convenient Methods for Estimation of Linear Regression Models with MA(1) Errors." *Can. J. Econ.,* 18.1 (1985): 106-116.

Miller, J. Scott, J. Richard Conner, and John E. Waldrop. *Survey of Commercial Catfish Processors—Structural and Operational Characteristics and Procurement and Marketing Practices.* Miss. Agr. and Forestry Exp. Sta. AEC Res. Rep. No. 130, Mississippi State University, 1981.

Newton, H. Joseph. *Timeslab: A Time Series Analysis Laboratory.* Pacific Grove CA: Wadsworth & Brooks/Cole Publishing Company, 1988.

Traill, Bruce. "Risk Variables in Econometric Supply Response Models." *J. Agr. Econ.,* 29 (1978):53-61.

Tronstad, Russell and Thomas J. McNeill. "Asymmetric Price Risk: An Econometric Analysis of Aggregate Sow Farrowings, 1973-86." *Am. J. Agr. Econ.,* 71.3 (1989):630-637.

U.S. Department of Agriculture. *Aquaculture Situation and Outlook Report.* Washington, DC: Econ. Res. Serv. AQUA-2, March 1989.

U.S. Department of Agriculture. *Feed Situation and Outlook Report.*Washington, DC: Econ. Res. Serv. Various issues.

Winter, John R. and James K. Whittaker. "Estimation of Wheat Acreage Response Functions for the Northwest." *West. J. Agr. Econ.,* 4.2 (1979):83-87.