Cost Efficiency of Catfish Farms in Chicot County, Arkansas: The impact of extension services

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Tulsa, Oklahoma, February 18, 2004

This material is based upon work supported by the Cooperative State Research Education and Extension Services, U.S. Department of Agriculture, under Agreement No. 2001-34454-10537.

Abstract

Cost efficiency measures of a sample of catfish farms in Chicot County, Arkansas are estimated using a data envelopment analysis technique. A measure of overall efficiency is used to determine operator's characteristics, farm practices, and institutional support services that are likely to lead to higher farm level cost efficiency. Results indicate that live catfish production could increase by 55% using the same level of inputs if all farms were operating at the minimum average cost curve. Higher feeding rate and availability of extension services were associated with increased cost efficiency. Higher stocking density affected overall efficiency negatively. The marginal value of extension contacts in Chicot County was estimated to be $2988. This study was conducted when catfish prices were at the lowest level in ten years. Some of the results are indicative of farms struggling to meet short-run financial obligations rather than normal farm practices.

Key Words: catfish, cost efficiency, data envelopment analysis, and extension services.

JEL Classification: C14, C24, D61

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Catfish is the leading sector of the U.S. aquaculture industry. Farm-raised catfish are produced primarily in Mississippi, Arkansas, Alabama, and Louisiana. The water surface area under catfish production totaled more than 76,570 hectares (190,000 acres) in 2000. Mississippi had 45,136 hectares (112,000 acres), which was 59% of the national total. Acreage for Arkansas, Alabama, and Louisiana were 12,493, 9,672, and 5,239 hectares (31,000, 24,000, 13,000 acres), representing 16%, 15% and 6%, respectively, of the total national production area. The national value of catfish sales exceeded $500 million in 2000 with the four states contributing 96% of the national total (NASS 2001). Catfish production in these four states is concentrated in the Mississippi Delta Region that is characterized by relatively high poverty rates compared to other parts of the U.S. The industry growth is an important tool in stimulating growth in other sectors of the economy in the delta region. Chicot County is located in the southeast corner of Arkansas bordering Mississippi and Louisiana and represents a typical catfish production system within the Delta Region.

Due to different economic factors, the live catfish price has fallen from around $1.65/kg to about $1.21/kg in 2001 and 2002 (Quagrainie and Engle, 2002). Given the fact that the seafood market demand in the U.S. is large, with the relative strength of the dollar, and current trade negotiations to further market access between the U.S. and exporting countries, it is expected that imports of aquaculture products into the U.S. market will continue to grow. In the long run, survival of catfish farms in the delta regions would depend on farmers' ability to produce live catfish at lower cost. This paper examines levels of cost efficiency and factors linked to higher cost efficiency measures of catfish farms in Chicot County, Arkansas. The paper is organized as follows. A brief review of data envelopment analysis (DEA) is presented in Section 2, focusing on calculation of cost efficiency measures. The analytical procedures used in this study are presented in Section 3. Description and sources of data are presented in Section 4. In Sections 5 and 6, the results of the study and the policy implications that arise are discussed.

Data Envelopment Analysis

The measurement of a firm’s productive efficiency is based upon deviations of observed output from the efficient production frontier. If a firm's actual production point lies on the efficient frontier, it is perfectly efficient. If it lies below the frontier then it is inefficient, with the ratio of the actual to potential production defining the level of efficiency of the individual firm. Approaches for estimating efficiency can be generally classified into parametric and non-parametric methods. The first approach involves the estimation of a stochastic production frontier, where the output of a firm is a function of a set of inputs, inefficiency and random error. However, this method imposes an explicit functional form and distribution assumption on the data. By contrast, a non-parametric method does not impose any assumptions about functional form and therefore is not subject to the problems of assuming an underlying distribution for the error term (Coelli).

The data envelopment analysis technique is a non-parametric method that identifies the best production practice within a sample. Efficiency is estimated as a ratio of output to inputs, based on differences between observed and best practice decision-making units (Farrell). DEA calibrates the level of efficiency by constructing an efficient frontier, which provides a yardstick for all decision-making units (DMUs). A DMU located on the frontier uses the lowest quantities of inputs to produce the same level of outputs, such that, DMUs using different combinations of inputs to produce different combination of outputs can coexist on the same efficient frontier. The DMUs on the efficient frontier are the best practice performers within the sample, and are given a score of one, whereas others DMUs outside the efficient frontier are inefficient and are given a score between zero and one (Charnes, Cooper and Rhodes). DEA compares efficiency from two points of view: output-expansion and input-contraction. The output-expansion model poses the question as to how much more output could be produced with given levels of inputs. In contrast, the input-contraction model evaluates how much a DMU could reduce inputs without lowering its output (Coelli). This study uses the inputs contraction, as farmers tend to have greater control over their inputs than over their output.

Figure 1 illustrates the efficient frontier for a sample of four catfish farms (A to D) that are assumed to produce live catfish (Y) using aggregated inputs (X). Joining A, B, and C gives rise to the line segments AB and BC, which represent combinations of the three best practice farms and form part of the technical efficient frontier or envelopment surface. Farms A, B and C make up the frontier because a linear combination of adjacent pairs generates the highest output given the same levels of inputs. Farm D is inefficient because it uses more inputs than B to produce less output. Note that farm D is compared with linear combinations of farms A and B (i.e., D's peer group) at point D_V because the ratio of output and input at points A, D_V and B are similar. Farm C is in a separate group as its output-input structure (i.e., the ratio of output and input) differs from A, D_V and B. As a result C is not used to evaluate D. The technical efficiency (TE) score of farm D that measures the extent to which production can be affected by factors not related to the (dis)advantage of farm size and other aspects of the farm's production process, is given by the ratio Y_DD_V/Y_DD. That is, the benchmark point D_V uses only Y_D D_V instead of Y_D D of inputs used by farm D to produce the same level of output (Y_D). In other words, D could produce the same level of output using only (Y_DD_V/Y_DD) of the input used to produce Y_D by using the best production practices demonstrated by farm A and B.

The overall technical efficiency (OE) score includes the combined influence of the technical and scale effects. OE is a gross measure of relative productivity as it captures all sources of variation in the ratio of output to input, including TE (Coelli). On the other hand, the scale effect (SE) measures the extent to which overall efficiency can be affected as the size of operation changes (i.e., SE = OE/TE). Under DEA, all catfish farms would be ranked in terms of their relative OE, regardless of the potential effect of scale. In other words, each farm is compared against the best performing farms of a similar size in terms of input intensity and output mix, thereby taking into account the potential effect of scale on the TE score.

In Figure 1, the OE frontier is represented by line OX, which depicts the highest ratio of output to input that was attained by farm B. The horizontal distance between the overall and technical efficiency frontiers captures the scale effect. The OE benchmark for farms A, C and D are points A_C, C_C and D_C. For example; the OE score for farm D is given by the ratio (Y_DD_C/ T_DD) and the SE is given by Y_DD_C/Y_DD_V. In addition, under input-contraction, the level of the technical efficiency score is always greater than or equal to the overall efficiency score. If the two scores are identical, OE efficiency is fully explained by TE. If TE is higher than OE, overall efficiency is partly determined by the effect of scale (Battese and Broca). The OE frontier in Figure 1, OX, represents TE under constant returns to scale (CRS) and line ABC represents the TE frontier under variable returns to scale (VRS) or pure technical efficiency frontier (Coelli).

3. The Empirical Model

Based on the suggestion by Charnes, Cooper and Rhodes, it is assumed that each catfish farm produces quantity of live catfish (Y_j) using multiple inputs ($X_{i,j}$) and each farm (j) is allowed to set its own set of weights for both inputs and outputs. The objective is to minimize the total cost of a selected farm (j_0). In a linear programming framework a DEA model that represents the cost-minimization approach can be stated as:

$$\begin{aligned}
&\underset{j}{Minimize}\ z_0 \quad = \quad w_i^T X_{jo}^* \\
&subject\ to \sum_j \lambda_j Y_j \geq Y_{j_0} \\
&\qquad\qquad X_{jo}^* \quad \geq \sum_j \lambda_j X_{i,j} \\
&\qquad\qquad \lambda_j \quad \geq 0,
\end{aligned} \tag{1}$$

where w_i is a vector of input prices for the ith DMU, superscript T is the transpose function, and X^*_{jo} is the cost-minimizing vector of input quantities for the ith DMU calculated by the LP, given the input prices w_i and output level Y_{jo}. Equation (1) represents the cost minimization under CRS technology. The score $w_i^T X^*_{j0}$ is the measure of minimum cost of farm j_0 under CRS technology and λ_j are inputs and output weights. A shown by Featherstone, Langemeier and Ismet, overall cost efficiency (OCE) is determined for each farm by the following equation:

$$OCE = w_i^T X_{jo}^* / w_i^T X_{jo}. \tag{2}$$

In Equation (2) the denominator $w_i^T X_{j0}$ is the cost incurred by farm j_0 to produce Y_{j0}, The numerator is the minimum cost of producing output Y_{j0} , given input prices and CRS technology (i.e., OCE equals the ratio of possible minimum cost to observed cost).

Coelli, Rao and Battese shows that the CRS model is only appropriate when the farm is operating at an optimal scale. Some factors such as constraints to production resources may cause the firm to be not operating at an optimal size. For example, size of operation may be determined by borrowing limits set by financial institutions. Equation (1) can be transformed to VRS technology model, by adding a restriction that sums the weights to one (i.e., the constraint $\sum_j \lambda_j = 1$ is added to Equation (1)). The objective function of this model would represent the minimum cost of the farm under VRS technology. The restriction eliminates scale effects from the analysis (Banker, Charnes and Cooper). In that case, efficiency of the farm is calculated using Equation (2) but replacing the numerator with the minimum cost under VRS technology. Scale efficiency is ratio of the minimum cost of the farm under CRS technology to minimum cost under VRS technology. The measure of SE, however, does not indicate whether or not scale inefficiency occurs because a farm is operating on a too large or a too small a scale, that is, is production characterized by decreasing or increasing returns-to scale. Assessing whether or not a farm is scale inefficient requires solving Equation (1) but adding a constraint that restricts the weights to be equal to or less than one (i.e., a restriction $\sum_j \lambda_j \leq 1$ is added to Equation (1)). The restriction imposes non-increasing returns-to scale (NIRS). If the value of the objective function is unequal to the value of the objective function under VRS technology, then increasing returns to scale exist for that farm. If they are equal, then decreasing returns to scale apply (Coelli, Rao, and Battesse).

In determining the factors influencing the efficiency measures, the Tobit (Tobin) models are often used. Tobit models are used because the calculated relative efficiency measures are censored between zero and one or can be scaled to be between zero and 100%. In addition, the Tobit model calculates both the marginal effect of the explanatory variable on the efficiency measure and the probability of improvement for inefficient farms (Greene). The Tobit model is specified as follows:

$$\begin{aligned} S_{ij} &= \beta_0 + \sum_{i=1}^{N} \beta_i Z_i + \eta_i && \text{if } \beta_0 + \sum_{i=1}^{N} \beta_i Z_i + \eta_i > 0 \\ S_{ij} &= 0 && \text{if otherwise.} \end{aligned} \tag{3}$$

In Equation (3), S_{ij} is the measures of relative efficiency for farm j, Z's are explanatory variables that influence relative efficiency of the farms, N is the number of explanatory variables, and β and η are parameters of the model and random error term respectively. Since the estimated efficiency measures are bounded between zero and one (or zero and 100%), a two limit (double bounded) Tobit is the model of choice (Greene).

The variables that are commonly included in the Z matrix in Equation (3) can be divided into three groups: socioeconomic and demographic characteristics of the farmers (e.g., age, gender, education and experience); farm practices (e.g., size of farm, type of feeds); and institutional support (e.g., marketing and availability of extension services). However, few studies have addressed the issue of efficiency of catfish farms in the U.S. A study by Featherstone, Langemeier and Ismet that examined efficiency of Kansas beef cow farms indicated that size of operation represented by the number of beef cows was important in explaining overall, pure technical and scale efficiency measures. These conform to the results obtained by Gillespie, Schupp and Taylor for ostrich and emu producers in Louisiana. A study by Morgan and Langemeier on a sample of Kansas's farms indicated that higher scores of overall efficiency were significantly concentrated on larger farms. Langemeier and DeLano used a sample of Kansas's farms to examine the relationship between overall efficiency and farm characteristics. They conclude that overall efficiency was significantly related to operator's age, farm size, and farm type. In a study to identify factors affecting technical efficiency of Missouri hop producers, Ben-Belhassen and Womack concluded that type of technology used in production and managerial skills were important in explaining level of productive efficiency. In these studies age was associated with experience or managerial skill of the farm operator. Farm size and farm type, respectively, were used to capture the influence of economies of scale and specialization in production. Other variables related to farm productive efficiency include: availability of credit (Mehdian et al); education of the operator (Gillespie and Rakipova); and debit-to-asset ratio (Rowland et all).

Another variable of interest is the availability of extension services. The impact of agricultural extension services on productive efficiency can be evaluated through its marginal product, where extension is considered as a factor of production (Patrick and Kehrberg), or as a factor explaining individual technical efficiency measures (Aigner, Lovell, and Schmidt; Dinar, Karagiannis and Tzouvelekas). Under the DEA approach, and for the first scenario, the extension variable will be included in Equation (1) as part of inputs. The assumption is that inefficient use of agricultural inputs is due to ignorance (Dinar, Karagiannis, Tzouvelekas). The second scenario includes the extension variable in Equation (3) as part of the Z matrix. This is based on the assumption that the impact of extension services on farm productivity is through output gain due to elimination of technical inefficiency.

Extension services for the aquaculture industry in Chicot County, Arkansas are provided through the University of Arkansas at Pine Bluff (UAPB) laboratory located in Lake Village, Chicot County. The laboratory provides complete bacteriological, parasitological, viral, histological, and water quality diagnostics support for fish health problems and other services free of charge. Apart from providing diagnostic services, station extension agents also assist farmers in the development of disease and water quality managerial skills. The services provided by these laboratories facilitate farmers' selection of optimal input-mixes and thus affects the overall cost efficiency under an existing set of technology and management alternatives. Including the extension variable in the Z matrix of Equation (3) allows calculation of cost savings associated with the use of extension services. In addition, the Tobit model explained in Equation (3) can be used to examine the importance of each of the production inputs in explaining efficiency measures. When the variables included in Equation (3) expressed as natural logarithms, the relative importance of the independent variable in explaining efficiency can be determined from the estimated coefficient. McDonald and Moffitt show that, in the Tobit model, the first partial derivatives of Equation (3) are proportional to the estimated Z_i coefficients. Thus, the most negative coefficient is the most important factor in increasing farm inefficiency.

Data and Methods

A structured questionnaire was developed and used to collect 2001 input-output data from catfish farms in Chicot County, Arkansas. Data collection included both mail surveys and personal interviews. Out of 85 farms in the county, 44 farms returned the questionnaires, of these, 30 farms had a complete dataset usable for this study. Five inputs were used for cost efficiency analysis: labor, cost of electricity for aerating the ponds, quantity of fingerings/stockers, quantity of feeds, and other costs which included expenditure on, fuel, telephone, pond repair, interest payments, and other miscellaneous purchases. Quantity of food fish produced in 2001 was used to measure output. Other data collected were on size of operation, experience of the operator and type of ownership,

Table 1 presents the summary statistics of variables used in the cost efficiency analysis on a per ha basis. The sample catfish farms employed about 15 people, on average. The minimum was 3 persons and the maximum was 62 persons. This included both hired and household farm labor, and full-time and part-time farm workers. The fingerling stocking density was around 12,416 fish per ha. The recommended stocking density for catfish farms in Arkansas is between 12,000 and 15,000 fingerlings per ha (Engle and Killian, 1996). There was great variation in feeding rate from 1 to 29 tons per ha. The average was 12 tons per ha. Expenditure on electricity and other miscellaneous inputs were, respectively, \$673 and \$1,610 per ha, on average. Cost of labor was about \$587 per person per ha. Cost of fingerlings and feeds were, respectively, \$39 and \$2,452 per ha. For cost of electricity and other miscellaneous expenditures, we assumed the law of one price, i.e., all producers faced the same relative price for these inputs (Chavas and Aliber, 1993).

The input-output and price data were used in the DEA model to calculate minimum cost of each farm under CRS, VRS, and NIRS technologies. Respective measures of technical efficiency for each farm were calculated as the ratio of minimum cost to total cost. Scale efficiency measure was calculated residually. The minimum costs under CRS, VRS and NIRS were estimated using onFront software (Färe and Grosskopf, 2000). Moreover, two Tobit models were used to examine the relationship between overall efficiency measures and inputs used in production and farm characteristics. The explanatory variables included in the first Tobit model were the natural logarithm of the five inputs, i.e., labor, cost of electricity, stocking density, quantity of feed, and cost of other miscellaneous inputs (Table 1). The second tobit model was specified as:

$$\begin{aligned} S_{ij}^{*} &= \beta_0 + \beta_1 z_1 + \beta_{12} z_1^2 + \beta_2 z_2 + \beta_{22} z_2^2 + \beta_3 z_3 + \beta_{32} z_3^2 + \beta_4 z_4 + \eta_i \\ where, \quad CS_j &= \frac{\partial S_{ij}^{*}}{\partial z_2}\left[w_i^T X_j \right] = \Phi\left[S_{ij}^{**} \right]\left[\beta_2 + 2\beta_{22} \right]\left[w_i^T X_j \right]. \end{aligned} \tag{4}$$

The explanatory variables included in Equation (4) were: experience of the operator in years (z_1), availability of extension services (z_2), size of the operation in ha (z_3), and type of ownership (z4). The squares of each variable were included in the model to capture the decreasing marginal effect of each variable. The extension service variable was measured as number of contacts between catfish farm managers and extension personnel in Lake Village. This included number of times the farm manger sought laboratory services for both diseases and water quality diagnoses and tests, and other contacts where extension personnel were involved in advising or training the farmer on any other issues related to catfish production. Ownership was represented as a dummy variable such that ownership=1, if the operator owned the farm; ownership=0, otherwise. Also, in Equation (2), CS_j is the estimated cost savingds of by farm j associated with using UAPB extension services, $\delta S^*_{ij}/\delta z_2$ is the partial derivative of S^*_{ij}, with respect to the extension services variable (z_2), $\Phi(.)$ is the cumulative normal density function, and S^{**}_{ij} is the estimated Tobit index for the cost efficiency measure, and other variables are explained in Equations (1) to (3). The summary statistics for variables used in Equation (4) are presented in Table 2. The average farm size was 123 ha with a maximum and minimum of 543 and 16 ha, respectively. Operator's experience in catfish production was up to 11 years. Extension contacts were about 33 contacts per farm with the maximum being 690, on average. About 16% of the catfish farms in Chicot County were leased.

Results and Discussion

Cost efficiency under CRS or overall cost efficiency ranged from 0.01 to 1. The average was 0.33 and a standard deviation of 0.24 (Table 3). Thus, on average, the live catfish production potentially could be increased by roughly 77% using the same level of inputs if each farm in the sample was overall efficient. Average cost efficiency under VRS was 0.45 with a standard deviation of 0.21. Thus, catfish farms in the sample could increase live catfish production by an average of 55% using the same input if each farm was operating along the minimum average cost curve. Scale efficiency was 0.73, on average, with a standard deviation of 0.32. About 61% of the farms were over 80% scale efficient. Individual analysis of the firms indicated that 10 of the firms had decreasing returns to scale and 17 firms had increasing returns to scale. Only two farms were scale efficient.

The estimated cost efficient scores were low as compared to other livestock studies. Featherstone, Langemeier and Ismet reported an overall efficiency score of 0.60 for Kansas beef cow farms. In Rowland et al (1998), overall efficiency for swine producers in Arkansas was estimated to be 0.67. However, 2001 was not a normal year for catfish farms in the U.S. The price of live catfish was at a record low. Input adjustment by catfish farms to cope with low output may have caused some farms to operate sub-optimally.

Table 4 represents results of the tobit model on the relationship between pure cost efficiency and inputs used in production. The focus is on pure cost efficiency; assuming that some farmers have no control over the size of operation (scale effect), thus, overall cost efficiency. The hypothesis that all variables included in the model have no influence on overall efficiency was rejected at the 5% level of significance. One variable was found to have a positive and significant impact on pure cost efficiency: feeding rate. Increase in feeding rate by one unit will increase pure cost efficiency by 0.18. Increase in overhead cost was associated with higher pure cost efficiency but was not statistically significant. Stocking density and labor use were negatively related to pure cost efficiency and significant at the 5% and 10% levels, respectively. Thus, lower stocking rate and labor use were linked to higher cost efficiency. Also, lower electricity use was associated with higher overall cost efficient but was non-statistically significant. Under normal conditions, higher feeding rates should parallel higher stocking density and aeration rates (higher use of electricity). For this study, the results suggest otherwise. Feeds are a major component of catfish farm operation and management costs. Low prices of live catfish may be forcing some catfish farms to feed less than the recommended amount while maintaining the recommended stocking density, obviously affecting total farm output and cost efficiency. Higher variation in output and input costs (Table 1) is indicative of heterogeneous choices of inputs-mixes by catfish farms in Chicot County. As farmers struggle to save costs, the tendency is to deviate from normal management practices so as to meet short-run financial obligations.

The importance of farmer characteristics, farm practices, and institutional support in explaining pure cost efficiency is reported in Table 5. The likelihood ratio test statistics, which tested the hypothesis that all variables included in the model were statistically insignificant, was rejected at the 5% percent level. The positive or negative sign on the estimated coefficients indicates that increased use of the variable increases or decreases cost efficiency. Except for the farm size, all signs are as expected. Experience of the operator and extension contacts were significantly associated with increase in farm cost efficiency but at a decreasing rate. Experienced operators were more cost efficient than new operators, which is understandable. As stated before, extension contacts facilitated resource allocation on catfish farms; thus, farm managers who frequently use the Lake Village extension services are likely to be relatively more cost efficient than others. Farm size was statistically associated with catfish farm inefficiency. The signs on the farm size (negative) and farm size squared (positive) indicate that farms that were either too large or too small were likely to be cost inefficient. These results differ from other studies in which larger farms were associated with efficiencies due to economies of scale. However, this may be due to the fact that these studies did not include the square of the variable representing the size of operation in order to capture the decreasing marginal effects of the variable. Moreover, catfish production involves many interlinked production activities, with complex decision-making processes occurring during the production process. Farms that are too large may not be able to take advantage of economies of scale. Type of farm ownership was statistically non-significant but negative. This indicates that leased farms are more likely to be cost inefficient. This may be due to increased land leasing costs.

The estimated coefficients for the extension contacts and extension contacts squared variables were used to calculate the cost savings associated with using the Lake Village, Chicot County extension services. The marginal effects in Table 5 are partial derivatives of Equation (3) with respect to the corresponding variables. The total marginal effect for the extension variable is about 0.013 (see Equation 4). The product of the total marginal effect and the total cost used in production is the cost saved by a farm for using the services. From Table 3, total cost was $223,037, on average. The marginal value of extension services in Chicot County is, therefore, $2,988 per contact (i.e., on average, for every extension contact, the farm saved $2,988). In 2001, extension agents in Lake Village made 1,858 extension contacts with catfish farms in Chicot County. Consequently, the catfish industry in Chicot County saved about $5.6 million through these services. At the county level, this is a substantial amount given the economic uncertainties facing the catfish industry.

Summary and Conclusion

This study estimated cost efficiency measures for a set of catfish farms in Chicot County, Arkansas. Chicot County is in the Delta Region where most catfish production occurs. Possible and feasible minimum costs under constant, variable, and non-increasing returns-to-scales technologies were estimated using data envelopment techniques for 2001. Minimum cost estimates were then used to estimate overall, pure, and scale cost efficiency scores for each farm in the sample. The estimated pure cost efficiency scores were then regressed on factors influencing efficiency. Estimated overall and pure cost efficiency scores were relatively low indicating room for greater improvement. About 61% of the farms were over 80% scale efficient. This indicates that, while most of the catfish farms were operationally inefficient, they were of optimal size. Most catfish farms could become more efficient by adjusting input use rather than by adjusting the scale of operation.

Experience of the operators and extension contacts were important factors positively influencing farm efficiency but at a decreasing rate. Farms that were too large or too small were likely to be inefficient. The marginal value of extension services in Chicot County was estimated to be $2,988 per contact. There were 1,858 extension contacts made by Lake Village extension agents in Chicot Count in 2001. This saved the catfish industry in Chicot County about $5.6 million.

Increased competition in the catfish industry requires catfish farms to be cost efficient for their own survival. Cost efficiency analysis allows identification efficiency levels, source of inefficiency and ways of improvement. As indicated in this study, farm level cost efficiency measures were relatively low. However, this study was conducted when catfish price was very low. As farmers struggle to meet short-run financial obligations, some of the decisions made may have ended to be sub-optimal.

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Table 1: Summary statistics of variables used in cost efficiency analysis

Variable	Mean	STD	Minimum	Maximum
Labor (number of workers/ha)	15.30	14.43	2.47	61.77
Cost of electricity ($/ha)	673.31	1,033.66	0.00	5294.93
Stocking rate (kg/ha)	5,629.46	1,904.08	1,120.83	11,208.30
Feeding rate (ton/ha)	12.00	4.99	1.14	28.91
Overhead ($/ha)	1,609.91	2,497.47	285.34	14,299.42
Output (kg/ha)	3,660.71	2,286.64	76.42	11,208.30

Table 2: Summary statistics of variables used in the Tobit Model

Variable	Mean	STD	Minimum	Maximum
Size of operation (ha)	123.42	128.14	16.19	533.80
Experience of operator (years)	8.35	2.81	0.00	10.52
Extension services (number of contacts)	32.93	123.29	0	690
Land lessee in the sample (%)	16.13			

Table 3: Results of cost efficiency analysis [1]

Variable	Mean	STD	Minimum	Maximum
Estimated minimum cost under CRS	38,128.49	33,721.66	509.44	126,311.59
Estimated minimum cost under VRS	65,927.72	43,889.82	10,413.23	172,928.76
Estimated minimum cost under NIRS	38,247.14	33,849.96	509.44	126,311.59
Average total cost used in production	223,037.39	317,332.37	21,212.05	1,503,635.73
Cost efficiency under CRS	0.31	0.29	0.00	1.00
Cost efficiency under VRS	0.53	0.27	0.12	1.00
Cost efficiency under NIRS	0.31	0.29	0.00	1.00
Scale efficiency	0.55	0.29	0.01	1.00

[1] Cost are in $ and CRS, VRS and NIRS represents constant, variable, and non-increasing returns-to scales technologies.

Table 4: Tobit model results on relationship among efficiency and input used

Variable	Estimated Parameter	Asymptotic Errors	Marginal Effects [1]
Constant	1.431	0.531	
Log of labor (number of workers/ha)	-0.074	0.040*	-0.065
Log of cost of electricity ($/ha)	0.002	0.034	0.002
Log of stocking rate (kg/ha)	-0.183	0.078**	-0.161
Log of feeding rate (tons/ha)	0.223	0.068**	0.197
Log of overhead cost ($/ha)	0.034	0.028	0.030
Likelihood ratio test statistics	25.418**		

[1] Marginal effects of the expected value are computed at the mean of dependent variable.

Single (*) or double (**) denotes, respectively, significance at the 10% and 5% level.

Table 5. Influence of Farm Characteristics on Pure Cost Efficiency

Variable	Estimated Coefficient	Asymptotic Standard Error	Marginal Effect
Constant	0.55818	0.16328	
Experience of the operators in years	0.03903**	0.01967	0.03371
Experience squared	-0.00207*	0.00096	-0.00179
Extension contacts	0.02515**	0.00569	0.02172
Extension contacts squared	-0.00482	0.00710	-0.00416
Farm size	-0.00278**	0.00121	-0.00240
Farm size squared	0.00001**	0.00000	0.00001
Type of farm ownership	-0.09542	0.13224	
Standard error of estimate	0.020461	0.00296	
Likelihood ratio statistics	47.86**		

[1] Marginal effects of the expected value are computed at the mean of dependent variable.

Single (*) or double (**) denotes, respectively, significance at the 10% and 5% level.

Figure 1: Technical Efficiency and Scale Effects