Technical Efficiency of the Milkfish Production in Taiwan

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I. Introduction

Milkfish and aquaculture in Taiwan have been maintained for about three hundred years. They have always had a significant importance in the agriculture and gross domestic product over the whole economy (see Appendix Table 1). The ratio of milkfish cultivated area to the total aquaculture area is always in the top five on the island. It decreases from 16,802 hectares in 1975 to 10,421 hectares in 1994 within the recent tweenty years (Taiwan Fisheries Yearbook). However, starting from 1986 there is a big fluctuation in the cultivated area as well as in the amount of production, implying that the cultivation of milkfish in Taiwan is facing some difficulties. There are two important factors affecting the production of the milkfish including the man-made factors such as the ability of operators and the natural factors such as the weather. Therefore, to examine the technical efficiency and the random factors which mainly affect the milkfish production , and to identify the factors that affect the efficiency will certainly be an important subject in the milkfish production in Taiwan.

The main research objectives in this paper include:

1. Evaluate the production technical efficiency and compare the efficiencies by size of farms and types of cultivation.

2. Estimate the different production efficiencies from the brackish water

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and fresh water cultivation, and different size of farms' so that the farmers can make their production decision on whether to replace the fresh water by the brackish water cultivation or not.

3. Analyze all the possible factors that affect the production efficiency and the extent of their effects.

4. Explore the direction and policy implications of milkfish cultivation for the future.

The data for this paper were obtained from a field survey of 90 respondents including aqua-farms with under 3 hectares, over 3 hectares, fresh water rearing and brackish water rearing farms for the year 1991. The sample of producers selected was proportional to the geographic distribution of ponds for milkfish in the main production area in Taiwan.

II.Theoretical Model

1. Stochastic Production Frontier Function

The hypothesis of Iso-quant curve suggested by Farrell(1957), composed a production frontier by the combination of inputs from individual farms which have the same production, and specified the production efficiencies, for the production frontier is a set of the same maximum milkfish production level of individual farms which uses some certain inputs with full efficiency. The production points on the frontier which represent the fully efficient maximum production ones, if which are not, the production points will allocate under the frontier.

The variations in production among aqua-farmers may be simply caused by the production inefficiency on the one hand; they may be also caused by some un-controlled random factors on the other hand. Similarly, inefficiency in agricultural production may be caused not only by the technical inefficiency of a farmer, but also by the random factors such as weather and environmental factors. For this reason, when using the "production frontier" to measure the technical efficiency of a farm, it is more realistic to use the stochastic frontier. The stochastic production frontier model, developed by Aigner Levell and Schmidt (1977), was used for this paper. Based on this model, the error term can divide into the stochastic error assuming with normal distribution and the technical efficiency error assuming with half-normal distribution.

First, we consider a production function is:

$$Y_i = f(X_i) + \varepsilon_i = f(X_i) + v_i - u_i \quad (1)$$

Where $\varepsilon_i = v_i - u_i$ represents the composed error of output. v_i is the stochastic error with a normal distribution $(0, \sigma_v^2)$ and $E(v_i) = 0$, $var(v_i) = \sigma_v^2$; u_i is the technical efficiency error with a half-normal distribution. That is, $u_i > 0$ and $E(u_i) = \sqrt{2\pi} \cdot \sigma_u$; $var(u_i) = (\frac{\pi - 2}{\pi})\sigma_u^2$, v_i and u_i are independent from each other.

The $f(X_i)$ term in equation (1) is the maximum output with a fixed amount of inputs. Y_i is the real production from each individual farm. Due to the effect from the composed error term (ε_i), the real output Y_i is therefore, different from the level of the potential maximum production $f(X_i)$. The separate probability density function of v_i and u_i are:

$$g(v_i \mid \sigma_v^2) = \frac{1}{(2\pi)^{1/2} \cdot \sigma v} \cdot \exp[-\frac{1}{2}(\frac{v_i}{\sigma v})^2] \quad (2)$$

$$h(u_i \mid \sigma_u^2) = \frac{1}{(2\pi) \cdot \sigma v} \cdot \exp[-\frac{1}{2}(\frac{v_i}{\sigma v})^2] \quad \text{when } u_i > 0$$

$$= 0 \qquad\qquad \text{when } u_i \leqq 0 \qquad (3)$$

Under the condition of v_i and u_i are independent from each other, the joint density function of $\varepsilon_i = v_i - u_i$ becomes:

$$f(\varepsilon \mid \sigma^2, \lambda) = \frac{2}{\sigma} \cdot f^{\star}\left(\frac{\varepsilon}{\sigma}\right) \cdot \left[1 - F^{\star}\left(\frac{\varepsilon \cdot \lambda}{\sigma}\right)\right] \qquad (4)$$

$$-\infty \leqq \varepsilon \leqq +\infty$$

Where $\sigma^2 = \sigma_v^2 + \sigma_u^2$, $\lambda = \frac{\sigma_u}{\sigma_v}$, $f^{\star}$ and $F^{\star}$ are the normal probability density functions and the cumulative density function respectively. The mean and the variance for ε_i is:

$$E(\varepsilon) = E(u) = -\sqrt{2\pi} \cdot \sigma_u$$

$$\text{var}(\varepsilon) = \text{var}(v) + \text{var}(u) = \sigma_v^2 + \left(\frac{\pi - 2}{\pi}\right) \cdot \sigma_u^2 \qquad (5)$$

Assuming Y_i in equation (1) is the linear function form of X_i, then

$$Y_i = \beta X_i + v_i - u_i \qquad (6)$$

Based on the distribution character of v_i and u_i and from equations (4) and (6) we can obtain a maximum likelihood function for n samples as:

$$\ln L = \ln L(Y \mid \beta, \lambda, \sigma^2)$$

$$= n \ln \frac{\sqrt{2}}{\sqrt{\pi}} - n \ln \sigma + \sum_{i=1}^{n} \ln(1 - F^{\star}[\frac{(v_i - u_i) \cdot \lambda}{\sigma}])- \frac{1}{2\sigma^2} \sum_{i=1}^{n} (v_i - u_i)^2 \quad (7)$$

By using the maximum likelihood method, we can calculate the parameter β of the production frontier function from equation (7). In addition, we can find the ratio of the composed error (λ) and the estimated values for the error terms σ^2, σ_v^2 and σ_u^2.

2. Estimation of the Technical Efficiency of Milkfish Rearing Farms

The production frontier is a track which traces all the connections of production points of the farm that have the best efficiency under certain fixed inputs. Based on this, we can compare the differences between the observed points and the production frontier. Therefore, the technical efficiency as estimated from the frontier function is, in fact, a concept of the relative efficiency. The technical efficiency value of a farm is the ratio of it real production, under a fixed input, to the production from a most efficient on the production frontier. Also, under the assumption of the stochastic production frontier, this relative value can not be directly used to estimate the potential maximum production due to the existence of the stochastic interference error, vi. Jondrow, Lovell, Materov and Schmidt (1982) further used the conditional expected value of the technology error term, u_i to estimate the technical efficiency for agricultural production. They used the maximum likelihood method to estimate the composed error term, ε_i followed by the conditional expected value to measure the expected value of u_i . When u_i is under the half-normal distribution, the conditional expected technical efficiency index can then be estimated by the stochastic production frontier method which is according to:

$$E(u_i \mid v_i-u_i)=\frac{\sigma_u\sigma_v}{\sigma}\left[\frac{F^{\star}\left[\frac{(v_i-u_i)\cdot\lambda}{\sigma}\right]}{1-F^{\star}\left[\frac{(v_i-u_i)\cdot\lambda}{\sigma}\right]}-\frac{(v_i-u_i)\cdot\lambda}{\sigma}\right] \qquad (8)$$

Where the definitions of σ^2、σ_v^2、、σ_u^2、λ、$f^\star$and $F^\star$are all defined previously as above. In the empirical analysis, the maximum likelihood method can be used to measure the estimates of λ 、σ 、σ_u and σ_v. By substituting these values into equation (8), we can calculate the technical efficiency of each individual rearing farm.

The empirical model of this paper uses Cobb-Douglas function as the production frontier function. Because farms with different sizes and different types of the cultivation, their expected production and their technical efficiencies are therefore, different. For this reason, it is necessary to estimate each case individually.

Assuming the production function of individual farms as follow:

$$Y_i=f(AE_i, LC_i, DK_i, IK_i) \qquad (9)$$

Where Y, AE, IC, DK, IK represent the farm revenue, the area of the pond, labor cost, direct production costs and indirect production costs, respectively. The term i represents four different kinds of the rearing farm including the farm with an area under three hectares, an area larger than three hectares, brackish water pond and fresh water pond.

Further assume that the C-D production function is a double logarithm type, equation (9) can then be re-written as:

$$\ln Y_i = \ln A_i + \beta_{i1} \ln AE_{ij} + \beta_{i2} \ln LC_{ij} + \beta_{i3} \ln DK_{ij} + \beta_{i4} \ln IK_{ij} + \varepsilon_{ij} \qquad (10)$$

Where (i = type 1, 2, 3, 4 ; j = farm 1, 2, ... n_i)

Where i represents four different rearing farms including the farm with an area under three hectares, with an area over three hectares, with brackish water rearing and with fresh water rearing. The value of n_i represents the sample number taking from different farms. A_i is a constant term, β_{ij} is the estimated parameter of different variables and ε_{ij} is the variance between production value of each farm and the value on production frontier, including the errors from the interference by the stochastic factor (v_{ij}) and the technical inefficiency (u_{ij}) by man-made error, $\varepsilon_{ij} = v_{ij} + u_{ij}$.

In empirical analysis, we will use the stochastic production frontier, as indicated by Aligner, Lovell and Schmidt (1977), the first and the second moment of the maximum likelihood method of equation (7) be substituted into equation (10) to obtain values of the estimated parameters A_i 、 β_{ij} 、 λ and σ^2. Then, we used the method of conditional expected technical efficiency, as reported by Jondrow, Lovell, Materov and Schmidt (1982) to estimate the production technical efficiency index of individual farm by using equation (8).

By using the Cobb-Douglas function for this paper, the parameter of each variable in the function can then be estimated accordingly. In addition, the sum of all the parameters or elasticities shows the return to scale of each type of the farm and different size of farms. A sum larger than one represents a farm has an increasing return to scale, while a sum of less than one represents a farm has a decreasing return to scale.

In addition, by estimating the production frontier function, we can also obtain the value of λ which is the ratio of the errors caused by the artificial technical inefficiency to the errors caused by the stochastic errors. If the value of λ is large enough which indicates the composed error is existenced; while $\lambda > 1$ means that the variances caused by the man-made technical inefficiency is larger than the variances caused by the stochastic error, while $\lambda < 1$ means the stochastic factor causes the larger error.

III.Empirical Results

1. Results of the Estimation of the Production Frontier Function

Table 1 shows the results of the estimation of the parameters for the stochastic production frontier function from sample farms and their related values. The estimated value for each parameter represents the production elasticity and the return to scale obtained from the input factors for each farm. The number in the parentheses are the t-values, the estimated value of λ represents the ratio of technical inefficiency error to the stochastic error (σ_u / σ_v), which can show what is the major reason that causes variances in efficiency among the farms. When λ value becomes significant, it indicates that the composed errors are existenced.

In addition, $\theta = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ represents the percentage of the man-made technical inefficiency error to the total errors. Therefore, the larger the θ value means the bigger the effect caused by the artificial technical inefficiency error.

(1) Farms with an Area under Three Hectares

As indicated in Table 1, among all other factors, cultivated area have the biggest elasticity of production. The next one is the elasticity of the direct production cost. All the production factors give a positive effect in this production frontier except the indirect production cost. The sum of the production frontier parameters is 0.981, very close to the constant return to scale of the production but with a slight decrease in the scale.

A value of λ = 1.424 (σ_v=0.486，σ_u=0.692) means that artificial technical inefficiency will affect the efficiency error of each farm more than that can be caused by the stochastic error. And a value of θ = 0.670 indicating that 67% of the efficiency error of farms comes from the man-made technical inefficiency error.

Since land is a scarce resource in Taiwan, most of the milkfish cultivation in Taiwan are under three hectares. They are all too small in size. In addition, because large amount of the capitals have to be invested during the course of cultivation, it is not possible to gain the benefit of the scale economics. This further affects the production efficiency and benefit of the cultivation. Therefore, a λ value larger than one means that the man-made technical inefficiency will cause more effects to the farm than that from the natural factors such as the weather effect.

(2) Farms with an Area over Three Hectares

The results of the estimation of the frontier function which show that, other than the labor cost, all other input factors have a positive effect on the production frontier. Of all the factors, the direct production cost has a largest production elasticity and the cultivated area gives the second. The sum of all the parameters is 1.027 indicating an increassing return to scale of production.

A value of λ equals to 0.975 (σ_v=0.269，σ_u=0.262) means that the efficiency error is mainly caused by the stochastic factors such as the weather changes. Large scale cultivation of milkfish has the benefit of scale economics as a result of its large area of cultivation. However, it is very easy to be affected by the natural environmental factors such as the weather changes. Once the environmental conditions are changed, huge mortality of the milkfish occurs making the bigger fluctuation in the loss for the farm. Therefore, the stochastic factor error is the major reason that causes the efficiency error in the larger farms.

A value of θ =0.485 represents that for the total efficiency error only 48.5% of it comes from the man-made technical inefficiency error and the rest mainly comes from the stochastic factor. For all the factors, the direct production cost has the largest elasticity of production, the production elasticity of the cultivated area is the second one. For all these reasons, the larger farms should increase their direct production cost such as the fry and feed costs in order to increase their farm revenue.

(3) Brackish Water Farms

Of all the estimated parameters in the stochastic function, all three factors have very significant effects to the farm revenue except the labor cost. Also, the direct production cost has the largest production elasticity and the cultivated area is the second one. The estimation of indirect production cost gives a negative value for its parameter indicating that the brackish water farm needs to cut down its indirect production costs. A value of 0.982 for the sum of all parameters reflects the fact that the return to scale is in a decreasing situation.

A λ =1.085 (σ_v=0.634， σ_u=0.688) reveals that the efficiency error of the brackish water farm mainly coming from artificial technical inefficiency error. The θ = 0.54 indicating that 54% of the efficiency error is caused by the man-made technical inefficiency error and the rest is caused by the stochastic error. Because the brackish water cultivation has been maintained in Taiwan for many years, the brackish water cultivation is still the major part of the milkfish production here. The technology of this type of cultivation has not been changed very much compared to the fresh water rearing. Judging from the results of the estimation of various parameters, it seems that the brackish water farm can increase its profit by increasing its direct production cost or by expanding its cultivated area.

(4) Fresh Water Farms

Of the four input factors for the fresh water farm, the labor cost and the direct production cost have significant effect to the production frontier, the other two factors are insignificant. The direct production cost has the largest elasticity of production and the indirect production cost has the second one. The sum of all parameters gives a value of 1.009 indicating that the return to scale has a trend of increasing.

A value of λ equals to 1.076 (σ_v=0.387， σ_u=0.416) indicates that the efficiency error among the farms is mainly caused by the variances in the management efficiency. A θ =0.537 reflects that 54% of the efficiency error is caused by the man-made technical inefficiency error. The fresh water cultivation of the milkfish has been promoted gradually only in these past ten years (see Taiwan Fisheries Yearbook). They are mainly located in the inland areas that have no easy access to the seawater. However, because the land price in the inland areas is more expensive than that near the sea shore, the fresh water cultivation uses the capital intensive method to replace the use of land and labor. It also uses the ways of high density of fry and deep water system for cultivation in order to compensate the expensive land and labor costs. However, because it is very high density in feeding, the growing rate of milkfish is slower and the feeding period becomes longer making the investment of fry, feed and the other costs relatively higher and hence affecting the management efficiency of the farm. For these reasons the efficiency error of this type of farm is mainly coming from the man-made technical inefficiency error. Judging from the results of the estimation of various parameters, it seems that the fresh water rearing farm has to increase its direct production cost in order to increase its farm revenue.

2. Estimation of the Technical Efficiency of Milkfish Rearing Farms

By using the conditional expected value method, as indicated by Jondrow Lovell, Materov and Schmidt(1982), the technical efficiency of aqua-farm for milkfish can then be estimated with using the results of the

Table 1 Estimates of Production Frontier Function of Milkfish Production in Taiwan (1991)

Parameter[1]		Size of Farm		Type of Rearing		Total
		Under 3 ha (n=48)	Over 3 ha (n=42)	Brackish water (n=53)	Fresh water (n=37)	(n=90)
Constant	lnA	0.051 (1.578)[3]	6.812 (4.081)***	0.075 (0.342)	-7.810 (-1.155)	0.023 (0.237)
Cultivating area	lnAE	0.449 (6.393)***	0.375 (3.042)***	0.198 (3.320)***	-0.222 (-1.272)	0.005 (0.010)
Labor cost	lnLC	0.295 (1.442)	0.029 (0.490)	0.004 (0.075)	0.130 (2.355)**	-0.002 (-0.082)
Direct capital input	lnDK	0.423 (1.917)*	0.475 (3.436)***	0.867 (19.386)***	0.599 (8.977)***	0.274 (8.858)***
Indirect capital input	lnIK	-0.186 (-0.597)	0.148 (2.421)**	-0.087 (-2.818)**	0.502 (1.684)	0.680 (19.861)
λ [2]		1.424	0.975	1.085	1.076	1.830
σ		0.845	0.376	0.936	0.568	0.102
σ_v		0.486	0.269	0.634	0.387	0.490
σ_u		0.692	0.262	0.688	0.416	0.896
$\theta = \frac{\sigma u^2}{\sigma v^2 + \sigma u^2}$		0.670	0.485	0.541	0.537	0.770
Log-L		61.491	83.986	53.530	61.460	105.58
Sum of coeffcient		0.981	1.027	0.982	1.009	0.957

Note: (1)Dependent variable in regression is farm revenue in logrithm (lnY).

(2) $\lambda = \sigma_u / \sigma_v$, $\sigma^2 = \sigma_v^2 + \sigma_u^2$.

(3)Estimates in parentheses are T-values, ***、** and * indicate that these estimates are significant at the 1%、5% and 10% significance level repectively.

estimated production frontier function. Table 2 shows the frequency distribution for the technical efficiency of different size of farms and types of farm expressed by the efficiency interval.

(1) Farms with an Area under Three Hectares

The estimated values on Table 2 show that about 81% of this type of farm has technical efficiencies distributed in the range from 0.5 to 1.0, with the highest of 1.0, lowest of 0.23 and average of 0.66. This means that on the average, the real production technical efficiency of farm is still 34% behind the production frontier with the fully technical efficiency. The median value is also 0.66, similar to that of average. This represents that the distribution of technical efficiency for all the farms with an ares under three hectares is pretty normal, no extreme value exists.

(2) Farms with an Area above Three Hectares

About 98% of farms have their technical efficiencies distributed in the range from 0.5 to 1.0. Among them, nineteen farms account for about 45.24% out of the 98%, are further distributed in the range of 0.8 to 0.9. The maximum technical efficiency value is 1.0, minimum is 0.50 and the average is 0.83. This average value of 0.83 is higher than that of the farms with area less than three hectares. The median value here is 0.84, only 0.01 different from the average value, therefore, generally speaking, the technical efficiency of farms with area larger than three hectares is higher than that of the farms with area less than three hectares. Furthermore, the distribution of the technical efficiency in this size of farm here is more concentrated, there is no extreme value to affect the frequency distribution.

(3) Brackish Water Farms

About 85% of the brackish water farms have their technical efficiencies distributed in the range from 0.5 to 1.0 with the maximum of 1.00, minimum of 0.27 and average of 0.68. This indicates that, on the average, the technical efficiencies of brackish water farms are 32% behind the production frontier value. The median value in this case is 0.69 which is only 0.01 different from the average indicating that there is a normal distribution and no extreme value affecting the system. If we further divide this type of the farm by the size of farm (i.e., larger or smaller than three hectares), Table 2 also shows that the farms with an area less than three hectares have the average of 0.66, maximum of 0.98 and minimum of 0.27 while the farms with an area larger than three hectares have the average of 0.69, maximum of 1.00 and minimum of 0.43 for the value of technical efficiency. All of these indicate that the distribution of technical efficiency are very normal in this systems with different size of farms.

(4) Fresh Water Farms

About 97% of the fresh water farms have their technical efficiencies distributed in the range from 0.5 to 1.0 with the maximum of 1.00, minimum of 0.48 and the average of 0.78, relatively higher than that of the brackish water system. The median value is 0.79, only 0.01 different from the average, indicates the normal distribution and the absence of extreme value to affect the distribution. Again, further distinguishing them by the size of farm, we can find that the farm having an area less than three hectares shows the technical efficiency an average of 0.76, maximum of 0.99 and minimum of 0.48. These are all higher than their counterpart in the brackish water system. The same is true for the farms with an area larger than three hectares which have the average of 0.79, maximum of 1.00 and minimum of 0.62, which are all higher than the brackish water system and are all more concentrate in distribution.

Based on the above, we can see that regardless the minimum or the average values of technical efficiency, the farm with an area larger than three hectares always shows its value higher than the system with smaller area, therefore, it is obvious that the farms bigger in size have the higher production technical efficiencies than the smaller farms. The cultivation of milkfish in Taiwan is a capital intensive industry. Very often one has to invest huge amount of capital per unit cultivated area therefore, large scale farms very often are easier to gain the benefits from the scale economics than the smaller farms. In addition, larger farms usually have the professional experience and enough capital for technical improvement and for purchase of the new equipment which make their technical efficiencies relatively higher. On the other hand, in order to compensate for the uneconomic situation caused by the smaller size, the smaller farms always adopt the high density feeding method. In order to diverse the risk in price drop, many owners of the smaller farm also mix other kinds of fish with the milkfish in the same pond. This also diversifies owners' management time and management ability for milkfish. All of these therefore, make the smaller farms have the relatively lower production technical efficiencies.

By comparing the brackish and the fresh water cultivation, we can find that the brackish water farms have an average technical efficiency of 0.68 which is lower that what the fresh water farms have of 0.78. The cultivation of milkfish has been conducted in Taiwan for more than three hundreds years in which the brackish water rearing is the method that has been used for many years. Also, this rearing technique is more fixed with very few changes. In addition, most of the traditional brackish water aquafarmers adopt the shallow bed cultivating method which makes the yield per hectare to be lower and hence makes the management and technical efficiency to be lower than that of the fresh water cultivation. On the other hand, most fresh water farms are far from the sea shore, the ponds in the inland areas are more expensive. In order to use the land resource effectively and to increase the benefits of the production, most fresh water farm owners adopt the dense cultivating method and invest large amounts of capital. Under the intensive use of the capital and the professional management, the yield per hectare is pretty high. Therefore, their technical efficiencies, on the average, are higher than that of the brackish water farms.

Besides, from λ values of all different types of farm, as indicated in Table 1 and the efficiencies distribution of various farms listed in Table 2, we can find that the higher the λ value the bigger the range of frequency distribution of their efficiency values are. For example, the farms have an area under three hectares has a λ value of 1.424 with efficiency values distributed from 1.00 to 0.23, while farms with area larger than three hectares have λ value of 0.975 with efficiency values distributed from 1.00 to 0.50. This is because that λ value is the ratio between the man-made technical inefficiency error and the stochastic interference error. A λ value larger than one indicates that the man-made technical efficiencies is larger than the stochastic error, resulting in a more scattered distribution for the technical efficiency values.

3. Factors Affecting the Technical Efficiency in Milkfish Rearing Farms

For measuring the factors affecting the technical efficiency in milkfish farms, in addition to the effect caused by the stechastic factors, the production and revenue variances are also the results of the man-made technical inefficiency errors. The man-made technical inefficiency errors are very possibly comes from producer's behavior or personal training and production characteristics of the rearing farm itself. This section will attempt to find the sources of variances of technical efficiency of milkfish rearing farms. The possible sources are age of farm operator, years of cultivation, years of education of farm operator, ratio of hired labor, cultivated area per laborer, degree of specialization, ratio of capital to labor and cultivated area. Taking these operating characteristics (see Appendix Table 2) as a basis for measuring the factors which affect the variation of technical efficiency in milkfish farms.

By using the efficiency values estimated in Table 2 as the dependent variable and the possible affecting factors as the independent variables, we can make the regression analysis for measuring the effective factors of technical efficiency in milkfish rearing farms. The results of these estima-

Table 2 Frepuency Distribution of the Technical Efficiency in Milkfish Rearing Farms,Taiwan, 1991.

Confidence interval	Rearing ponds below 3 ha	Rearing ponds over 3 ha	Brackish water pond			Fresh water pond			Total
			Under 3 ha	Over 3 ha	Total	Below 3 ha	Over 3 ha	Total 3 ha	
>0.0≦0.1	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)
>0.1≦0.2	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)	0(0 %)
>0.2≦0.3	2(4.14%)	0(0 %)	1(3.57%)	0(0 %)	1(1.89%)	0(0 %)	0(0 %)	0(0 %)	5(5.56%)
>0.3≦0.4	2(4.17%)	0(0 %)	2(7.14%)	0(0 %)	2(3.77%)	0(0 %)	0(0 %)	0(0 %)	4(4.44%)
>0.4≦0.5	5(10.42%)	1(2.38%)	2(7.14%)	3(12.00%)	5(9.43%)	1(5.00%)	0(0 %)	1(2.70%)	4(4.44%)
>0.5≦0.6	6(12.50%)	2(4.76%)	5(17.86%)	5(20.00%)	10(18.87%)	3(15.00%)	0(0 %)	3(8.11%)	14(15.56%)
>0.6≦0.7	14(19.17%)	3(7.14%)	7(25.00%)	7(28.00%)	14(26.42%)	4(20.00%)	4(23.53%)	8(21.62%)	16(17.78%)
>0.7≦0.8	8(16.67%)	7(16.67%)	5(17.86%)	4(16.00%)	9(16.98%)	5(25.00%)	7(41.18%)	2(32.43%)	18(20.00%)
>0.8≦0.9	5(10.42%)	19(45.24%)	4(14.29%)	4(16.00%)	8(15.09%)	4(20.00%)	4(23.53%)	8(21.62%)	14(15.56%)
>0.9≦1.0	4(8.33%)	10(23.81%)	2(7.14%)	2(8.00%)	4(7.55%)	3(15.00%)	2(11.76%)	5(13.51%)	15(16.67%)
Maximum	1.00	1.00	0.98	1.00	1.00	0.99	1.00	1.00	1.00
Minimum	0.23	0.50	0.27	0.43	0.27	0.48	0.62	0.48	0.22
Mean	0.66	0.83	0.66	0.69	0.68	0.76	0.79	0.78	0.78
Middle value	0.66	0.84	0.67	0.69	0.69	0.78	0.79	0.79	0.77
Samples	48	42	28	25	53	20	17	37	90

Source： Calculated from field survey data tion are listed in Table 3.

(1) Farms with an Area under Three Hectares

The variables that contributes the significant effects include the cultivated area per labor and the size of cultivation, they all have positive effects. The reason for this is that, on the average, each farm only has a cultivated area of 1.49 hectares which is too small in size therefore, they have to make relatively high investment in capital for making them possible to gain the benefit of the scale economics. As to the cultivated area per labor, this value is only 0.56 hectare for each farms causing the over-investment of capital and labor input and hence affecting the technical efficiency in cultivation. For this reason, an increase in the farm size will have a significant effect on the technical efficiency for this type of farm. The results of the regression analysis show that the variables of cultivated area per labor and the the size of cultivation have a positive relation to the technical efficiency. Again, it shows that an increase in the farm size will increase the technical efficiency. Other variables considered include the age of the opeator, the number of the years in cultivation and the capital to labor ratio do not agree with what has been expected.

(2) Farms with an Area over Three Hectares

Among those variables, the number of the years in cultivation, years of education of farm operator and the degree of specialization have the positive effects while the age of the farm operator gives the negative effect. All other variables show insignificant effect. Many reasons can be used to explain these results. For example, the longer the years in cultivation gives the more time in accumulating experience and in improving the production efficiency. The higher the educational training makes its easier to accept new knowledge and technology. The higher the degree of specialization means that the farm has put more productive resources into the production of the milkfish only. This will eventually increase its technical efficiency. As to the age of the farm operator it shows a negative relationship, reflecting that the older the age the worse the ability in managing the farm.

(3) Brackish Water Farms

Both the ratio of hired labor and the number of years in cultivation show the positive effects. This means that the higher the hiring ratio of labor the higher the production technical efficiency due to the labor shortage in aqua-farm families. In addition, the number of years in cultivation also has a positive relation with the technical efficiency, this means that the longer the years in aquaculture the more the time in accumulating experience for handling different matters in the farm, including arrangement for the equipment, prevention of fish disease, forecasting the weather changes and making decisions on the amount of the resources to be invested, etc.

(4) Fresh Water Farms

The age of farm operators shows a negative effect while the degree of specialization and the ratio of capital to labor have the positive effects. This indicates that most of the fresh water cultivation of milkfish in Taiwan also culture other kinds of fish. As a result of the diversified production, the technical efficiency for the milkfish dropped. For this reason it is necessary to increase the degree of specialization in milkfish culture. In addition, it is necessary to use capital intensive mothods to replace the labor used and to increase the ratio of capital to labor in order to increase the culture efficiency.

The above discussions show that for each type of cultivation, there are different ways of increasing for their own efficiencies. However, based on the present type of milkfish cultivation in Taiwan, the small farms are still the major part of the rearing systems with the lower production efficiency. A possible way or direction to improve the technical efficiency of production is to increase the cultivated area per labor through joint business in

Table 3 Estimates of Effective Factors of Technical Efficiency in Milkfish Rearing Farms, Taiwan, 1991.

Factors	Size of Farm		Type of Rearing		Total
	Under 3 ha (n=48)	Over 3 ha (n=42)	Brackish water (n=53)	Fresh water (n=37)	(n=90)
Age of farm operator	0.005 (1.450)	-0.009 (-3.727)***	-0.007 (-1.010)	-0.008 (2.306)**	-0.009 (0.871)
Years of cultivation	-0.001 (-0.355)	0.007 (2.862)***	0.008 (2.242)**	0.001 (0.158)	0.004 (2.331)**
Educated years of farm operator	0.005 (0.511)	0.010 (2.116)**	0.007 (0.931)	0.015 (0.319)	0.009 (0.875)
Ratio of hired labor	-0.091 (-0.865)	0.031 (1.027)	0.561 (2.522)***	0.023 (0.365)	0.511 (2.977)***
Cultivated area per labor	0.102 (2.206)**	0.013 (0.977)	-0.011 (-0.577)	0.029 (0.781)	-0.058 (-1.543)
Degree of specilization	0.190 (1.276)	0.289 (2.241)**	0.384 (1.505)	0.012 (2.048)**	0.390 (2.057)**
Ratio of capital to labor	-0.015 (-1.482)	0.015 (1.597)	0.003 (0.392)	0.074 (3.208)***	0.034 (0.155)
Size of cultivation	0.017 (2.093)**	0.002 (0.784)	0.003 (0.504)	0.017 (1.399)	0.122 (2.566)**
Constant	0.081 (2.506)**	0.243 (2.498)**	0.045 (0.263)	0.163 (1.146)	0.119 (1.157)
F-value	47.96***	230.81***	64.14***	104.74***	33.56
R^2	0.29	0.57	0.34	0.63	0.45

Note：Numbers in parentheses are T-values，***、** and * indicate that these estimates are significant at the 1%、5% and 10% significance level, respectively.

the milkfish industry.

IV.Conclusions

This paper has aimed to estimate the technical efficiency of milkfish production, and to identify the important factors that affecting the variation of efficiency of the milkfish farms in Taiwan. The stochastic production frontier model was used and estimated by using data from a recent field survey with different size of farms and types of cultivation. From the empirical results, importance issues can be concluded as follows:

(1) The empirical results of production frontier estimated by stochastic frontier function, showed that all factor inputs in average, the direct production cost had a greatest production elasticity, and the labor cost had a least. In different types of rearing, direct production cost caused greatest production elasticity in small farms, large farms and fresh water rearing farms. Besides, the estimated λ values which represented the ratio of disturbance terms were larger than 1 in small farms, brackish and fresh water rearing farms, it indicated that the efficiency error mainly came from man-made technical inefficiency in these rearing farms. Where the λ value estimated from large farms was smaller than 1, it indicated that the production error was caused from stochastic disturbances.

(2) The estimation of technical efficiencies from individual farms showed that, the greatest value of efficiencies was 0.83, estimated from the large farms, the second one was 0.78, it was estimated from fresh water rearing farms, the least one was estimated from small farms, the value was only 0.66. In addition, the difference between the greatest and least efficiency was very significant in the same type of rearing farms, it meant that there were some important factors which caused the significant differences in technical efficiencies among milkfish farms.

(3) The variations of milkfish production efficiency between different types of rearing farms had different sources. Cultivated area per labor and size of cultivated area had positive significant effects in small farms. Age of farm operator, years of education of farm operator and degree of specialization were the main sources of efficiency variation in large farms. Brackish water farms with positive significance were affected by the ratio of hired labor and years of cultivation. The age of farm operator, degree of specialization and the ratio of capital to labor affected the technical efficiency in fresh water farms.

From the results of estimation of the technical efficiencies of milkfish farms, we can see that for the same type of rearing farms, their technical efficiencies are quite different. It is obvious that many factors will affect the ways each farm put its input and hence makes significant differences in their technical efficiencies. These factors include the management ability of the operator, the scale of the farm and stochastic interference factors etc.. If we can promote the effective use of farm resources and the improvement of operator's ability for farming, this will not only can increase the production efficiency, but also can lessen the differences of efficiency among farms. Production efficiency of individual farm is affected by many factors, therefore, it is necessary to identify those factors before they can improve their technical efficiencies. The analysis as made by this paper already identified those important affecting factors.

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Appendix

Table 1 Relative Importance of Milkfish and Aquaculture to Agricultural Production and Gross Domestic Product, Taiwan, 1993.

Gross Domestic Product:	
Agriculture	3.50%
Industries	40.60%
Services	55.90%
Agricultural Production:	
Crops	42.73%
Forestry Products	0.31%
Fishery Products	25.28%
Livestock Products	31.68%
Fishery Products	
Far-sea Fisheries	45.83%
Off-shore Fisheries	18.55%
Coastal Fisheries	3.51%
Aquaculture*	32.11%
Milkfish Products: NT$ 1,919 million	
Aquaculture Products: NT$ 29,919 million	
Milkfish as % of Agriculture:	0.52%
Aquaculture as % of Agriculture:	8.12%
Milkfish as % of GDP:	0.03%
Aquaculture as % of GDP:	0.52%

* Aquaculture includes marine culture, inland fishing and inland culture.

Source:(1)Taiwan Agricultural Yearbook, 1994.

(2)Taiwan Fisheries Yearbook, 1994.

(3)Taiwan Statistical Data Book, 1994.

Appendix

Table 2 Characteristics of Sample Farms of Milkfish Rearing, Taiwan, 1991.

Farm type / Item	Average (n=90)	Size of Farm		Types of Rearing	
		under 3 ha (n=48)	over 3 ha (n=42)	brackish water (n=53)	fresh water (n=37)
Age of farm operator(year)	50.37 (11.53)	51.75 (9.87)	48.73 (13.07)	50.13 (11.63)	50.72 (11.38)
Years of cultivation	21.10	21.05	21.17	24.88	15.68
Educated years of farm operator	6.69 (4.68)	5.86 (4.11)	7.68 (5.12)	5.97 (4.78)	7.19 (4.55)
Ratio of hired labor[1]	0.38 (0.32)	0.28 (0.31)	0.52 (0.33)	0.35 (0.17)	0.40 (0.38)
Cultivated area per labor[2] (ha/man)	1.10 (1.27)	0.56 (0.43)	1.62 (1.69)	1.18 (1.46)	0.98 (0.94)
Degree of specialization[3]	0.83 (0.16)	0.69 (0.47)	0.85 (0.15)	0.87 (0.09)	0.78 (0.23)
Ratio of capital to labor[4]($/$)	2.72 (2.19)	2.53 (1.19)	3.01 (2.67)	2.71 (2.56)	2.76 (1.52)
Size of cultivation(ha)	5.37 (7.11)	1.49 (0.63)	9.80 (8.42)	5.44 (8.28)	5.27 (4.13)

Notes:1.Ratio of hired labor=hired workers÷(home workers+hired workers).

2.Cultivated area per labor=cultivated area÷number of total labor.

3.Degree of specialization=milkfish production revenue÷(milkfish production revenue+revenue from other species).

4.Ratio of capital to labor=capital cost÷labor cost.

5.Numbers in parentheses are standard errors.

Source: Calculated from field survey data.

台灣虱目魚養殖技術效率之分析

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摘要

本文旨在探討虱目魚養殖農場之生產技術效率，並估測影響農場間技術效率差異的重要因子。經由隨機性邊界函數估測，其結果顯示：在各種投入因素中，直接生產成本的生產彈性最大，而勞動支出的生產彈性為最小。在各種飼養規模農場中，小規模飼養場以養殖面積的生產彈性為最大，而大規模飼養場則以直接生產成本的生產彈性為最大。就生產的技術效率而言，大規模飼養場的平均技術效率為最高，達0.83，而小規模飼養場僅有0.66。至於影響虱目魚飼養場間技術效率差異的因子，在小規模飼養場中，每一勞動者的經營面積及養殖規模對技術效率具有正向的顯著影響；而大規模飼養場的技術效率差異，主要為場主年齡、養殖經驗、教育程度以及專業特性等因子具有顯著的影響。

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