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Economies of Scale in Shrimp Farming Industry in Iran

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Abstract: In this study, the presence of scale economies, an important production technology characteristic, in shrimp farming industry, is examined jointly with the input elasticity of substitution and factors price elasticities. To this end, a dual Translog cost function was estimated, using data from 51 shrimp farms in southern province of Iran. Results revealed that scale economies exists in the Iranian shrimp farming industry, meaning that there is a good potential to reduce the unit cost of production by choosing an appropriate size for the shrimp farms in Iran.

Key words: Shrimp farms · Scale economies · Production technology · Factor elasticity of substitution · Iran

INTRODUCTION

Shrimp farming in Iran is one of the main activities in fishery sector. Shrimp farming is an important job creating and foreign currency generating activity, while using non arable land. In the recent years, an increase in cost of production from one hand and a decrease in the prices received by producers due to a decline in the world price of the shrimp and the stable exchange rate in Iran from other hand have resulted to a decline in profitability and consequently the contraction of this activity in Iran. A cost pushed increase in price of shrimp has led to a reduction in domestic demand for this product and caused losing its share in international markets. To address these challenges, the shrimp farmers have to find ways to reduce their cost of production. Given that, an analysis of production structure in shrimp farming, specifically, investigating the presence economies of scale in this industry might provide valuable information [1, 2] .

The main objective of this study is to provide such information by estimating a cost function using farm data from 51 shrimp farms in southern province of Iran. Specifically, this study attempts to investigate the presence of scale economies, to determine elasticity of input substitution and the price elasticites of input demands in shrimp farming in Iran.

MATERIALS AND METHODS

Duality theory postulates that the production structure can be investigated by estimating a cost function as a dual to the production function. The cost function approach has several advantages; generally more flexible functional form can be specified without placing a priori restriction on the parameters of the production technology and the parameters of interest can be derived with less difficulty since the cost function takes as arguments factor prices rather than quantities which are more likely to be exogenous to a firm, more readily observed, and are less likely to exhibit multicollinearity [1]. Accordingly, most of the studies dealing with production structure specifications have utilized a dual approach using a cost function. One of the most common functional forms utilized by these researches to represent the production thechnology is the translog form which is a flexible functional form so that it imposes no restriction on factor substitution and allows scale economies changes with the level of output and inputs [2]. The translog cost function has been utilized in plenty of studies concerning different aspects of production structure such as economies of scale, factor substitution, technical change, factor price elasticity and factor productivity by many researchers [1-5]. Many others have followed this approach for investigating production specification in different countries including Iran [6-11].In line with these researchers; a dual cost function with a translog functional form is used to study the structure of production of shrimp farming industry in Iran. The general form of translog cost function is given by the following equation [6]:

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$$\ln C = b_0 + b_q \ln Q + 1/2\, b_{qq} (\ln Q)^2 + \sum_i b_i \ln p_i + 1/2 \sum_i \sum_j b_{ij} \ln p_i \ln p_j + \sum_i b_{iq} \ln p_i \ln Q \quad (1)$$

Differentiations of the above cost function with respect to input prices, using Shepard's lemma gives the following cost share equations:

$$S_i = b_i + b_{qi} \ln Q + \sum_j b_{ij} \ln p_j \quad (2)$$

In the above equations, C is total cost of shrimp production, Q is production quantity, S_i is the ith input cost share, p_i is the price of ith input, and b_i, b_{qi} and b_{ij} are parameters to be estimated. To be a valid cost function, the above function has to satisfy the regularity conditions. The symmetry condition is satisfied if $b_{ij}=b_{ji}$ and the linear homogeneity in factor prices requires $\Sigma_i bi=1$, $\Sigma_i b_{iq}=0$ and $\Sigma_i b_{ij}=\Sigma_j b_{ij}=\Sigma_i \Sigma_j b_{ij}=0$ restrictions. Furthermore, concavity in prices requires the matrix of second order partial derivatives of the cost function with respect to input prices be negative semidefinite [12-15]. This condition is satisfied when the own Allen elasticities of factor substitution or own price elasticities of factor demand are negative for all the observations [9,15]. Monotonicity in input prices requires the cost shares to be grater than zero, and monotonicity in output requires that marginal cost be greater than zero at the point of approximation [9].

Translog cost function does not constrain the production structure to be homothetic nor does it impose restrictions on the elasticities of substitution. However, these restrictions can be tested statistically. A cost function corresponds to a homothetic production function if and only if, it can be expressed as a separable function in the output and input prices. A homothetic cost function is further restricted to be homogenous if, and only if, the elasticity of cost with respect to output is constant. For the translog cost function homotheticity requires that $b_{qi}=0$. Furthermore, homogeneity is satisfied if $b_{iq}=0$, and $b_{qq}=0$ in addition to the b_{qi} being zero. Restrictions for the unitary elasticity of substitution can be tested by eliminating the second order terms in the prices so that $b_{ij}=0$ [12].

Berndt and Wood [16] have shown that for a translog cost function the Allen elasticities of substitution and price elasticities of demand for the inputs are calculated as follows:

$$s_{ij} = \frac{b_{ij} + S_i S_j}{S_i S_j}$$
$$s_{ii} = \frac{b_{ii} + S_i^2 - S_i}{S_i S_j} \quad (3)$$

$$\varepsilon_{\iota\varphi} = \Sigma_\varphi \sigma_{\iota\varphi}$$
$$\varepsilon_{\iota\iota} = \Sigma_\varphi \sigma_{\iota\iota} \quad (4)$$

Where; σ is Allen elasticity of factor substitution and ε_{ii} and ε_{ij} are own and cross price elasticities, respectively. Standard errors that correspond to these elasticities can be calculated as [14-15]:

$$ES_s = STE(b_{ij})/S_i S_j$$
$$ES_e = STE(b_{ij})/S_i \quad (5)$$

Where; STE (b) is standard error of b and S_i and S_j are cost shares of ith and jth inputs.

Elasticity of scale is usually defined in term of an increase in output resulting from a proportional increase in the quantity of all inputs. From a cost function, the scale elasticity is defined as the inverse of cost flexibility which is the derivatives of cost with respect to output. That is,

$$\eta_C = \partial \ln c / \partial \ln Q = b_q + b_{qq} \ln q + \sum_i b_{qi} \ln p_i \quad (6)$$

$$\eta_s = \partial \ln Q / \partial \ln C = (\eta_C)^{-1} \quad (7)$$

Where; η_s is scale elasticity and η_c is cost flexibility. With the above definitions, $\eta_s>1$ implies economies of scale in production, while $\eta_s<1$ implies diseconomies of scale in production [15]. Therefore, given the parameter estimates of the cost function, one can specify the existence of the scale economies in the production technology in shrimp farming industry.

According to Ray [4] a joint estimation of the cost function and the input cost shares adds the efficiency of parameter estimates. Accordingly, this approach is followed in this study using the nonlinear maximum likelihood procedure. This system was estimated using data from 51 shrimp farms in southern province of Iran which was collected in 2001. Inputs used in shrimp production in one period of production are capital, labour, feed, larva, fuel and other materials. Thus, the total cost (C) of production in one farming period is total payment for these inputs. In the present study the prices of labour (p_w), feed (p_f) and larva (p_l) were calculated by dividing their respective costs by their purchased quantities. Since fuel consists of oil, petroleum, gas oil and gasoline, a weighted price index of these components has been used as price of the fuel (p_o). Capital input used in shrimp farming is simply the air system utilized to increase availability of oxygen in the water pool. Since some of the farms are not equipped with this system, a dummy variable (D_1) is used to capture the effect of this capital input. A different dummy variable (D_2) is used to account for the other materials used in some of the farms.

RESULTS AND DISCUSSION

To specify the most appropriate model for presenting production structure of shrimp farming, five different models were estimated. These are; (A) a model without any dummy variables, (B) a model with both dummies, (C and D) two models, each with only one of the two dummy variables, and (E) a model with interaction of two dummies. The likelihood ratio test was used to test validity of each of the five models. The value of likelihood function, likelihood ratio test and the critical χ^2 for five percent significance level for the models are given in Table 1. As indicated in the table, comparing the calculated test statistics with the critical values of χ^2, show that supports model A with no dummy variable included in the list of independent variables. Hence, model (A) is selected to present the production structure of the shrimp industry.

In estimating parameters of the model the square of output (Q^2,) was omitted from model as it showed severe multicollinearity with Q. The estimated parameters are presented in Table 2. As it is shown in the table, most of the parameters (13 out of 20) are significant at 5 percent significant level. The coefficients of output quantity, as well as prices of feed, labour and fuel inputs are statistically significant at 5 percent level, whereas estimated parameter of larva price is insignificant. Insignificant variation of larva price paid by different shrimp farmer might explain this result.

To check for correct model specification, the normality of the error term was tested using jarque-bera procedure. The normality of the error terms supported the correct specification of the model. Furthermore, the estimated own Allen elasticities of partial substitution for all the inputs were checked for all data points. Negative sing of calculated elasticities showed that the concavity condition of cost function is satisfied. In addition, the positive sing of calculated marginal cost and input shares from equation, is an indication of satisfying monotonicity condition by the estimated model.

Table 1. Comparing different models.

	A	B	C	D	E
R^2	0.83	0.85	0.85	0.84	0.84
Log-Likelihood Value	427.39	431.09	429.85	427.97	428.75
Likelihood Ratio test		7.39	4.90	1.15	2.72
χ^2		19.67	11.07	11.07	11.07
		(DF=11)	(DF=5)	(DF=5)	(DF=5)

DF = Degree of freedom R^2= R-Squared between observed and predicted.
A: C = f (Q, Pl, Pf, Pw, Po) B: C = f (Q, Pl, Pf, Pw, Po, D1, D2)
C: C = f (Q, Pl, Pf, Pw, Po, D,) D: C = f (Q, Pl, Pf, Pw, Po, D2)
E: C = f (Q, Pl, Pf, Pw, Po, D1*D2)

Table 2: Estimated parameters of translog cost function

Parameter	Parameter value	t-statistics	Parameter	parameter value	t-statistics
b_0	5.108	22.62	b_{fl}	-0.042	-0.69
b_q	0.408	10.35	b_{wl}	-0.073	-3.13
b_l	0.009	0.11	b_{ol}	0.026	3.96
b_f	-0.252	-2.80	b_{fw}	-0.012	-0.45
b_w	1.168	20.44	b_{fo}	0.000	0.00
b_o	0.076	5.90	b_{wo}	-0.005	-1.73
b_{ll}	0.089	1.50	b_{lq}	0.031	2.43
b_{ff}	0.054	0.77	b_{fq}	0.119	9.00
b_{ww}	0.091	4.15	b_{wq}	-0.138	-15.79
b_{oo}	-0.020	-2.88	b_{oq}	-0.013	-7.49

For testing homotheticity, a homothetic model was tested against a non-homothetic model. Results are presented in Table 3. Since, Q^2 was omitted from the model; the homothetic restriction is equivalent to the homogeneity restriction. Comparing likelihood ratio test with the critical χ^2 for 5 percent significance level indicate that the restrictions are rejected. Hence production technology in shrimp farming industry is not homothetic and homogeneous. Furthermore, testing the unitary elasticity of input substitution is rejected as reported in Table 3.

Table 4 reports own and cross price elasticities of factors demand. As this table shows, all own price elasticities are negative. The estimated standard errors of the elasticities revealed that own price elasticities for feed, labour and fuel inputs are significant at 5 percent level, whereas the own price elasticity for larva is insignificant. The magnitudes of elasticities reported in Table 4 show that demand for fuel is elastic, whereas demand for feed and labour are inelastic. The inelasticity of feed and labour indicates the important role of these inputs production process and the inflexibility of shrimp farmers in response to prices increases of these two inputs.

Table 3: Testing homotheticity, homogeneity, and unitary elasticity of input substitution of production technology in shrimp farming

Parameters	Unrestricted model	Homothetic and homogenous model	Model with Unitary elasticity of substitution
b_0	5.108 (22.62)	4.753 (1.358)	5.071 (22.87)
b_q	0.408 (10.35)	0.470 (5.812)	0.405 (10.38)
b_l	0.009 (0.011)	0.156 (3.736)	0.041 (0.458)
b_f	-0.252 (-2.805)	0.457 (6.599)	-0.215 (-2.663)
b_w	1.168 (20.44)	0.383 (6.595)	1.083 (14.703)
b_o	0.076 (5.90)	0.004 (0.402)	0.091 (7.883)
b_{ll}	0.089 (1.50)	0.081 (1.463)	-
b_{ff}	0.054 (0.77)	0.013 (0.166)	-
b_{ww}	0.091 (4.15)	0.091 (2.315)	-
b_{oo}	-0.020 (-2.88)	-0.021 (-2.87)	-
b_{fl}	-0.042 (-0.69)	-0.017 (-0.293)	-
b_{wl}	-0.073 (-3.13)	-0.087 (-3.681)	-
b_{ol}	0.026 (3.96)	0.023 (3.331)	-
b_{fw}	-0.012 (-0.49)	0.001 (0.031)	-
b_{fo}	0.000 (0.00)	0.003 (0.259)	-
b_{wo}	-0.005 (-1.73)	-0.005 (-1.140)	-
b_{lq}	0.031 (2.43)	-	0.034 (2.170)
b_{fq}	0.119 (9.00)	-	0.119 (8.375)
b_{wq}	-0.138 (-15.79)	-	-0.140 (-10.85)
b_{oq}	-0.013 (-7.49)	-	-0.012 (-5.961)
LLF	427.143	389.437	400.555
LRT		75.41	53.18
$X^2_{0.05}$		11.07	18.31

t-statistics are in parentheses.

LLF= Log-Likelihood Function. LRT= Likelihood Ratio Test

Table 4: Input price elasticities at the mean level of observations

	Larva	Feed	Labour	Fuel
Larva	-0.388 (0.236)	0.287 (0.232)	-0.031 (0.70)	0.132 (0.030)
Feed	0.146 (0.118)	-0.429 (0.137)	0.261 (0.057)	0.022 (0.023)
Labour	-0.025 (0.082)	0.417 (0.091)	-0.396 (0.075)	0.000 (0.011)
Fuel	1.379 (0.312)	0.461 (0.468)	0.046 (0.142)	-1.887 (0.328)

Estimated standard errors are in parentheses

Table 5: Allen elasticities of factor substitution at the mean level of observations

	Feed	Labour	Fuel
Larva	0.607 (0.568)	-0.098 (0.351)	5.926 (1.245)
Feed		0.910 (0.200)	0.999 (1.022)
Labour			0.153 (0.487)

Cross price elasticities presented in Table 4 reveal economically substitution or complementary relationships between inputs. Estimated standard errors show that the cross price elasticities for feed and labour as well as fuel and larva are significant at 5 percent level. The signs of these parameters show economically substitution relationship between all these inputs. While cross price elasticities for the other inputs are insignificant, their signs can reveal economically substitution relationship except for larva and labour that are economically complement. These findings are not unexpected. For example, by hiring more labour and distributing the feed with more care by spending more time, the amount of feed consumption can be reduced. In the case of substitution between larva and fuel, it seem one can reduce casualties of larva by using more fuel for pumping fresh water into the pools or for oxygenating water.

Table 6: Estimated scale elasticities for different output level

Output quantity (100 Kg)	Scale elasticity	Output quantity (100 Kg)	Scale elasticity
7600	1.64	30977	1.71
10000	1.63	32046	1.72
11149	1.73	32136	1.58
11731	1.78	32845	1.61
12055	1.53	34515	1.62
18376	1.59	34600	1.67
19670	1.65	35449	1.57
19838	1.37	35852	1.55
20010	1.67	35938	1.78
20290	1.76	36549	1.63
20806	1.68	37078	1.71
22000	1.65	38939	1.47
22622	1.61	39467	1.48
23800	1.69	39677	1.72
24726	1.69	40000	1.63
24862	1.68	41200	1.72
25150	1.63	42546	1.75
25967	1.63	45647	1.67
27378	1.67	51320	1.67
27647	1.64	52100	1.71
28530	1.59	52289	1.61
28624	1.67	53200	1.55
28804	1.67	53533	1.71
29650	1.56	56171	1.58
29873	1.61	60600	1.65
30000	1.73		

Estimated Standard Errors Are in Parentheses: The calculated economy of scale as reported in Table 6 is 1.69 for average of data points. This supports the presence of scale economies in production technology of shrimp production in Iran. This parameter was calculated for all the shrimp farms and the results are presented in Table 6. As this table shows, the magnitudes of scale economies for all observation are greater than one, indicating the existence of scale economies in all the farms under consideration. Since production technology in this industry is not homothetic, scale economies are not the same for all the farms, but it differs for different farms and depends on the levels of output produced and input prices.

CONCLUSIONS

The analysis of the production structure of the shrimp farming industry provides some result that might be interesting to shrimp farm managers as well as policy makers in this newly developed industry in Iran. First of all, results indicate that, own price elasticity of demand for larva is very small (inelastic). The inelasticity of this input, in turns indicates inflexibility of shrimp producers in response to any increase in the price of this essential input. Given the presence of some sort of monopoly power in the larva market, the shrimp production is at risk of cost increase. Therefore, it seems actions that prevent more monopolization in larva supply are necessary and it is wise to be implemented. Since price elasticity of demand for feed and labour are also inelastic, the inflexibility of producers is a problem as well for these two inputs. However, since based on the results, there is a substitution relationship between feed and labour inputs in the process of shrimp production, there is a possibility that shrimp farmers substitute labour for the feed as the latter input constitutes more 50 percent of production cost in this industry. This substitution is recommended as a means of reducing per unit cost of production. Also, results indicate the possibility of substitution between larva and fuel. It seems reasonable to provide easy access of farmers to the fuel to be used in more water filtration and ventilation. This will result in reducing larva mortality rate which in turns, will reduce per unit cost of production.

Finally, results revealed the presence of economies of scale in the shrimp farming industry in Iran. This finding is very important as it indicates the potential of reducing the cost of production in this industry by increasing the size of the farms under consideration. Given that the products of this industry are mostly exported, increasing the size of the farms to an optimal one is a good strategy in reducing per unit cost of production and thus, increasing the competition power of the shrimp industry in the international market [15-18].

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