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Efficiency Analysis of Fishery in Hamoon Lake: Using DEA Approach

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Abstract: The aim of this study was to estimate technical, allocative and economical efficiency of selected fishermen in Hamoon Lake southeastern of Iran. Dataset applied in the study included cross sectional data that obtained from 74 questionnaires, completed among Sistanian fishermen in 2004. DEA approach is applied in this study. The use of the DEA index is free of distributional and production related assumptions in its derivations and is therefore not subject to the same potential for bias. The average technical efficiency of selected sample, using DEA approach, was calculated 82.7%. These figures for allocative and economic efficiencies were 75.5 and 62.7%, respectively. In addition, two components of technical efficiency including net technical efficiency and scale efficiency were calculated. Regarding that economic inefficiency results from both technical and allocative inefficiencies, so the harvests will perform economically efficient by rising technical and allocative efficiencies. Although, differences in efficiency among vessels were small in this study, vessels which their skippers participated in extension classes and those who did not have financial problem were more efficient. In addition, bigger capacity vessels technically and economically were more efficient.

Key words: Iranian fisheries, Hamoon lake, efficiency, DEA approach

INTRODUCTION

Efficiency in production is a way to ensure that products of firms are produced in the best and most profitable way. To prevent waste of resources, efficiency is of great importance for every sector in the economy. In addition, fishermen in Sistan region are facing with problems of unemployment, low income, drought, financial limitation, implying that the sensitivity of efficiency gap will become more sever.

Following Farrel (1957) one can describe technical and allocative efficiency of firms. From the output perspective, technical efficiency measures the potential increase in output, keeping the inputs constant. Allocative efficiency from the output perspective is simply the revenue maximizing problem. Technical efficiency from the input perspective measures the ability of the firms to produce a given output using the smallest set of inputs. Allocative efficiency in this case measures the firm's ability to allocate the input bundle in the cost minimizing way. Combining measures of technical and allocative efficiency yields a measure of economic efficiency. The output and input perspective will coincide when measuring technical efficiency under constant returns to scale. The allocative and economic efficiency measures however are completely different in nature and are not likely to coincide for other reasons than by chance.

Various degrees of inefficiency in production seem to be the rule rather than the exception. Bailey *et al.* (1989) estimated technical, allocative and economic efficiency on a sample of Ecuadorian dairy farms. They found a positive relationship between size and technical efficiency. In contrast to the New England study, medium-sized Ecuadorian farms were found to be as allocatively efficient as large farms. Bravo and Rieger (1991) examined technical, allocative and economic efficiency of a sample of New England dairy farms, using the Stochastic Frontier Approach (SFA) and a Cobb-Douglas production function. They found overall economic inefficiencies of on average 30%. However it was little difference between mean technical (83.0%) and mean allocative efficiency (84.6%). Heshmati and Kumbhakar (1994) examined the technical efficiency of Swedish dairy farms, during period of 1976-1988, excluding 1985, using the stochastic frontier approach and a translog production function. They found that the mean technical efficiency indices were between 0.81 and 0.83. This indicates technical inefficiencies of almost 20 % in the Swedish dairy farms. Jonasson (1996) used DEA approach and measured various output efficiencies of a sample of Swedish farms during 1989-1991. He found that the average technical and allocative output efficiencies where 0.95 and 0.92, respectively. Lansink *et al.* (2002) studied technical efficiency of Finnish farms, using the Data Envelopment Analysis (DEA). They found that the conventional livestock farms

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had technical efficiency scores of 69%. A possible reason for the great difference between the two studies in Sweden is that Jonasson didn't aggregate output in DEA. Adding an extra output or input in DEA will never cause a reduction of the efficiency scores and a greater number of outputs and inputs compared to the total number of observations will always cause greater efficiency scores. Thus, the difference is much likely to depend on the differences in the methods. Although data envelopment indices should not be used for comparison between different studies (Coelli *et al.*, 2002), since the scores only measure the relative efficiency within the sample, there are evidence of technical, allocative and economic inefficiencies in dairy farms (Coelli *et al.*, 2002).

Although many researches conducted to investigate the efficiency of fishery in the world (Kirkley *et al.*, 1995; Sharma and Leung, 1999; Pascoe *et al.*, 2001; Fousekis and Kolonaris, 2003; Kompas *et al.*, 2003; Tigley *et al.*, 2005) only few studies could be found in Iran (Yazdani and Esmaeili, 1995; Esmaeili, 2006). Data Envelopment Analysis (DEA) is recently developed approach for measuring efficiency in fisheries (Felthoven; 2002; Pascoe and Herrero, 2004).

Hamoon Lake is located in southeastern of Iran. This Lake is the biggest freshwater Lake in Iran, which its water source is Hirmand River from Hendokosh Mountains in Afghanestan. The Hamoon Lake area is around 5000 km^2 which share between Iran and Afghanestan. Fishery from Hamoon Lake is important for local economy.

The main purpose of this study is to examine the technical efficiency for the fishery industry in Iranian part of Hamoon Lake.

MATERIALS AND METHODS

The idea behind efficiency studies is to measure a firm's position relative to an efficient frontier, resulting in an efficiency score of the firm. The efficiency scores will be bounded between zero and one, where a score of one indicates full efficiency. Measurement of efficiency requires knowledge of the efficient production function, which thus has to be estimated from the sample data.

As was pointed out in the previous section, DEA is technique of estimating a firm's relative position to the frontier. When using DEA, estimation via the production, cost or profit function is possible. The cost and profit functions are both dual to the production function and thus they can be derived from the estimates. Cost and profit functions have the advantage of allowing for multiple outputs (Coelli, 1996). Data envelopment analysis developed by Charnes *et al.* (1978), is a non-parametric approach. The production frontier in DEA is deterministic, so any deviations from the frontier are related to inefficiency. DEA approach is very useful for multi product activities such as fishery in Hamoon Lake.

The idea behind DEA is to use linear programming methods to construct a surface, or frontier around the data. Efficiency is measured relative to this frontier, where all deviations from the frontier are assumed to be inefficiency. Consider n firms producing m different output using h different inputs. Thus, Y is an m×n matrix of outputs and X is an h×n matrix of inputs. Both matrices contains data for all n firms. The Technical Efficiency (TE) measure under the assumption of Constant Returns to Scale (CRS), can be formulated as follows:

$$\begin{gathered} \min \theta \\ \text{Subject to } -y_i + Y\lambda \geq 0 \\ \theta x_i - X\lambda \geq 0 \\ \lambda \geq 0 \end{gathered} \tag{1}$$

and solved for each firm in the sample. θ_i is firm i's index of technical efficiency relative to the other firms in the sample. y_i and x_i represents the output and input of firm i respectively. $Y\lambda$ and $X\lambda$ are the efficient projections on the frontier. A measure of $\theta_i = 1$ indicates that the firm is completely technically efficient. Thus, $1 - \theta_i$ measures how much firm i's inputs can be proportionally reduced without any loss in output. However, the assumption of CRS is correct only as long as firms are operating at an optimal scale (Coelli *et al.*, 2002). Various constraints on inputs like financing and the goals of the owner may cause the firm to operate at a non-optimal scale. Using the CRS DEA model when firms are not operating at their optimal scale will cause the TE-measures to be influenced by scale efficiencies and thus the measure of technical efficiency will be incorrect. By adding a convexity constraint to the model above VRS is instead assumed:

$$\begin{gathered} \min \theta \\ \text{Subject to } -y_i + Y\lambda \geq 0 \\ \theta x_i - X\lambda \geq 0 \\ NI'\lambda = 1 \\ \lambda \geq 0 \end{gathered} \tag{2}$$

The new constraint is $NI'\lambda = 1$ where N1 is a n×1 vector of ones. This constraint makes the comparison of firms of similar size possible, by forming a convex hull of intersecting planes, so that the data is enveloped more tightly. The technical efficiency measures under VRS will always be at least as great as under the CRS assumption. In order to derive the economic efficiency of the firm, the following model is solved:

$$\min xi' x_i^* \quad \text{Subject to } -y_i + Y\lambda \geq 0 \quad x_i^* - X\lambda \geq 0 \quad NI'\lambda = 1 \quad \lambda \geq 0 \tag{3}$$

Where:

x_i' : The firm i's vector of input prices

x_i^* : The cost minimizing input bundle faced by firm i. The economic efficiency for firm

i : Then solved by the following computation:

$$EE = w_i'/w_i'x_i \tag{4}$$

that is, the observed cost is compared to the minimum cost the firm would face if using the optimal input bundle. Furthermore, the Allocative Efficiency (AE) of firm i can be calculated as follows:

$$AE = \frac{EE}{TE} \tag{5}$$

AE measures firm i's relative ability to allocate the input-bundle in the cost minimizing way, given the estimated technology.

Dataset applied in this study include cross sectional data from Iranian part of Hamoon Lake. The information was collected through face-to-face interviews with skippers in 2004.

RESULTS

The data of this study was obtained by completing 74 questionnaires among a randomly selected sample of Hamoon fish harvesters in 2004. However, the selected sample accounts for 40% of fishermen population. A harvesting unit contains a head - harvester and some of the normal harvesters, competing with each other.

The income share of normal harvesters from fish sale is as a percentage of total income, since harvesting units, instead of the number of harvesters, was applied. So, their income depends on the total amount of harvesting fish. But, the head- harvester due to providing harvesting facilities, such as boat and automobile for selling, gets considerable part of income. Different species of harvested fishes, regarded as outputs, are Common carp (*Cyprinus carpio*; Y_1), Grass carp (*Ctenopharyngoden idella*; Y_2), Silver carp (*Hypophthalmichthys molitrix*; Y_3), Big head (*Aristichthys nobilis*; Y_4) and Schizothorax (*Schizothorax zarudnyi*; Y_5. The inputs are also as follow:

X_1: The number of harvesters of group

X_2: The number of motor-powered boats

X_3: The number of harvesters transferring automobiles.

X_4: Net size.

X_5: Annual cost of timber.

X_6: Annual insurance cost of the group's members

X_7: Annual cost of harvesting permission

X_8: Annual costs of strip.

X_9: Annual cost of fuel.

The normal harvesters are managed by their head-harvester. The harvested output is transferred by motor-powered boats from the lake to the coast and by truck from coast to sale to cooperatives and retailers. Net size is the most important input in harvesting. The wider the net size the more output will be obtained. Timber and annual permission are of other inputs that were used in terms of their costs. Insurance was also considered in terms of its cost. The rest of inputs are strip length and amount of fuel.

Based on the relationship presented in methodology for DEA approach, technical, allocative and economical efficiencies under two assumptions, constant and variable returns to scale, were estimated. The results revealed that the differences between technical efficiencies under two assumptions are not statistically significant. Under variable returns to scale, technical efficiency is divided into net technical and scale efficiencies.

Findings of Table 1, shows that harvesters have a good performance from managerial viewpoint and their net technical efficiency is near to one. Therefore, harvesters with respect to their activities and returns to scale can increase technical efficiency by changing the amount of inputs. This finding is similar to Esmaeili (2006), who analyzed fishery industry in the northern Persian Gulf using frontier model. As the results showed 44 farms have increasing returns to scale, 29 of them perform under constant returns to scale, while only one farm has decreasing returns to scale (Table 2). That is, for half of harvests, increasing the amount of inputs will result in decreased output, while those with constant returns to scale can expect the same change rate for output as they change the amount of the input. Most researchers found increasing return to scale for fishery industry. For instance, Fousekis and Kolonaris (2003), Garcia Del Hoyo *et al.* (2004) and Esmaeili (2006) calculated returns to scale of 1.26, 2.65 and 1.42, respectively.

Technical efficiency was estimated under input minimizing assumption. Average technical, allocative and economical efficiencies for selected sample are 82.7, 75.5 and 62.7%, respectively (Table 3). Hence, economical inefficiency comes from both of the technical and allocative inefficiencies; although allocative efficiency is lower than technical one. Frequency distributions of efficiencies are showed in Table 4. The result of the DEA analysis does not only indicate the efficiency scores of the units, but also the reference frequencies of units which are the last performing.

In the case of technical efficiency the highest frequency accounts for range of 0.9-1, while for allocative efficiency range of 0.7-0.8 has the most frequency, indicating that Sistanian harvesters fall short to allocate inputs in a cost-reducing way (Table 4).

Due to the non-parametric structure of the data (unbalanced distribution), the Mann Whitney U-test was used (instead of regular t-test) for statistical analysis in order to compare the mean efficiency between groups of vessels. The result of statistical analysis indicates that, on the whole, vessels with higher than 2 tons capacity technically and economically are more efficient ($p<0.01$).

Table 1: Mean, minimum and maximum of technical efficiency and its components

	Data envelopment analysis		
Parameters	TE	NTE	SCA
Mean	0.827	0.995	0.831
Minimum	0.202	0.756	0.202
Maximum	1.000	1.000	1.000

Table 2: Returns to scale of the harvests

Returns to scale	No.	%
IRS	44	59.45
DRS	1	1.35
CRS	29	39.18

Table 3: Mean, minimum and maximum of technical, allocative and economical efficiencies

	Data envelopment analysis		
Parameters	TE	AE	EE
Mean	0.827	0.755	0.627
Minimum	0.202	0.331	0.165
Maximum	1.000	1.000	1.000

Table 4: Frequency distribution of technical, allocative and economic efficiency

	Efficiency measure and number of firms		
Interval	TE	AE	EE
<0.1	0	0	0
0.1-0.2	0	0	2
0.2-0.3	4	1	5
0.3-0.4	3	1	7
0.4-0.5	1	2	9
0.5-0.6	2	10	12
0.6-0.7	4	11	7
0.7-0.8	10	20	12
0.8-0.9	12	17	10
0.9-1.0	38	12	10

This result is similar to Sharma and Leung (1999), Tigley *et al.* (2005) and Esmaeili (2006) findings. In addition, the technical efficiency in vessels which their skippers participated in extension classes were significantly more that other ones ($p<0.05$). Finally, vessels with financial security are allocatively and economically less efficient than other group ($p<0.05$). This difference might be due to risk averse of skippers who had financial limitation.

DISCUSSION

Estimation of the efficiency in fisheries is becoming important as the distribution of efficiency has a considerable impact on the effectiveness of effort controls and profitability of fisheries. In this paper, using DEA approach and under two assumptions of constant and variable returns to scale, technical, allocative and economic efficiencies of Sistanian fish harvesters were estimated. In addition, two components of technical efficiency including net technical efficiency and scale efficiency were calculated. Relatively few examples of the case of DEA approach in fisheries exist for the purpose of estimating efficiency. The use of the DEA index is free of distributional and production related assumptions in its derivations and is therefore not subject to the same potential for bias (Pascoe and Herrero, 2004).

Based on the results, the mean of technical, allocative and economical efficiencies were obtained 82.7, 75.5 and 62.7%, respectively. However, differences in efficiency among vessels were small in this study; differences in efficiency are often attributed to differences in technology and the skill of the skipper (Sharma and Leung, 1999; Herrero and Pascoe, 2003). The technology used in the vessels is similar, so skipper skill is likely to be the major factor affecting vessels efficiency. Although, all information on skipper specifications is not available for all vessels in this study, but according to available data, vessels which their skippers participated in extension classes and those did not have financial limitation were more efficient. In addition, bigger capacity vessels technically and economically are more efficient. This result is similar to Sharma and Leung (199), Tigley *et al.* (2005) and Esmaeili (2006) findings.

Result from both technical and allocative inefficiencies, indicated that harvests could perform economically efficient by rising technical and allocative efficiencies.

Present findings also showed that allocative efficiency is less than technical one by a little, indicating the disability of harvesters in reducing costs. Lower amount of scale efficiency is of main cause of low technical efficiency, therefore the fisherman can enhance their technical efficiencies by using more inputs.

REFERENCES

Bailey, D., B. Biswas, S.C. Kumbhakar and B.K. Schulthies, 1989. An analysis of technical, allocative and scale inefficiency: The case of ecuadorian dairy farms. West. J. Agric. Econ., 14: 30-37.

Bravo-Ureta, B. and L. Rieger, 1991. Dairy farm efficiency measurement using stochastic frontiers and neoclassical duality. Am. J. Agric. Econ., 73: 421-428.

Charnes, A., W.W. Cooper and E. Rhodes, 1978. Measuring the efficiency of decision making units. Eur. J. Operat. Res., 2: 429-444.

Coelli, T., 1996. A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. CEPA Working Paper 96/08, Centre for Efficiency and Productivity Analysis, University of New England.

Coelli, T., P.D.S. Rao and G.E. Battese, 2002. An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers, London.

Esmaeili, A., 2006. Technical efficiency analysis for the Iranian fishery in the Persian Gulf. ICES J. Mar. Sci., 63: 1759-1764.

Farrel, M.J., 1957. The measurement of productive efficiency. J. Roy. Stat. Soc., 120: 253-281.

Felthoven, R., 2002. Effects of American fisheries act on capacity, utilization and technical efficiency. Mar. Resour. Econ., 17: 181-205.

Fousekis, P. and S. Kolonaris, 2003. Technical efficiency determination for fisheries: A study of trammel netters in Greece. Fish. Res., 63: 85-95.

Garcia, D.H., J.J. Castilla, D. Espino and J.R. Toribio, 2004. Determination of technical efficiency of fisheries by stochastic frontier models: A case on the Gulf of Cadiz (Spain). ICES J. Mar. Sci., 61: 416-421.

Herrero, I. and S. Pascoe, 2003. Value versus volume in the catch of the Spanish south Atlantic trawl fishery. J. Agric. Econ., 54: 325-341.

Heshmati, A. and S.C. Kumbhakar, 1994. Farm heterogeneity and technical efficiency: Some results from Swedish dairy farms. J. Prod. Anal., 5: 45-61.

Jonasson, L., 1996. Mathematical programming for sector analysis-some applications, evaluations and methodological proposals. Thesis of Swedish University of Agricultural Sciences.

Kirkley, J.DS. and I. Strand, 1995. Assessing technical efficiency in commercial fisheries: The mid-Atlantic sea scallop fishery. Am. J. Agric. Econ., 77: 686-697.

Kompas, T., T.N. Che and R.Q. Grafton, 2003. Technical efficiency effects of input controls: Evidence from Australia's banana prawn fishery. Working Paper No. 03-3. Australian National University.

Lansink, O.A., K. Pietola and S. Backman, 2002. Efficiency and productivity of conventional and organic farms in Finland 1994-1997. Eur. Rev. Agric. Econ., 29: 51-65.

Pascoe, S., J. Andersen and J.D. Wilde, 2001. The impact of management regulation on technical efficiency of vellels in Dutch beam trawler fishery. Eur. Rev. Agric. Econ., 28: 187-206.

Pascoe, S. and I. Herrero, 2004. Estimation of a composite fish stock index using data envelopment analysis. Fish. Res., 69: 91-105.

Sharma, K. and P. Leung, 1999. Technical efficiency of the long-line fishery in Hawaii: An application of a stochastic production frontier. Mar. Res. Econ., 13: 259-274.

Tigley, D., S. Pascoe and L. Coglan, 2005. Factors affecting technical efficiency in fisheries: Stochastic production frontier versus data envelopment analysis approaches. Fish. Res., 73: 363-376.

Yazdani, S. and A. Esmaeili, 1995. Investigating the economic efficiency of fishery industry in Bandar Lengeh Iran. J. Agric. Sci., 26: 41-47.