Vol.7 No.4 (2010) p32-38 **Journal of Management Science & Statistical Decision**

AN ANALYSIS TO SCALE EFFICIENCY OF FISHERY PRODUCTION IN ZHEJIANG PROVINCE

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ABSTRACT. *In this paper, three kinds of DEA model are employed, which are CCR, BCC and FG models respectively, to analyze the scale efficiency and returns to scale of industry of fishery production in Zhejiang province from 1999 to 2008. It is found that the scale is efficient only at the year of 1999, 2005, 2007, and the other years are inefficient. It is also found that if the scale is inefficient, returns to scale of fishery production is increasing, which implies the industry should increase input to improve efficiency.*

Keywords: Data Envelopment Analysis (DEA); Fishery Production; Scale Efficiency

1. Introduction. In recent years, increasing attention has been paid to the performance of fisheries. Performance assessment, optimization, and policy making of fishery production are very important issues for regulators in the production restructuring and reform. Nowadays, various methods are used for estimating efficiency scores of fishery production units. These methods are generally classified as parametric and non-parametric methods. Corrected ordinary least squares and stochastic frontier analysis are parametric models and DEA, PCA and NT are non-parametric models. Oliveira et al. (2009) used Malmquist indexes to explore the evolution of productivity of the artisanal dredge fleet that operates in the south coast of Portugal. Data Envelopment Analysis was implemented to estimate and assess capacity utilization and efficiency for the first time in the eastern Mediterranean by Christos D. Maravelias in 2008. Herrero (2005) applied four different approaches (data envelopment analysis, stochastic production frontiers, panel data and distance functions) to the Spanish Trawl fishery that operated in Moroccan waters. Fu-Sung Chiang (2004) specified a stochastic production frontier function to estimate potential milkfish farm output and efficiency by using 1997–1999 data from a survey of 433 aquaculture milkfish farms. In this paper we will compare CCR, BCC and FG models, three models of DEA, to analyze the scale efficiency of fishery production in Zhejiang province of China.

Efficiency measurement has been a subject of tremendous interest as organizations have struggled to improve productivity. Reasons for this focus were best stated fifty years ago by Farrell (1957) in his classic paper on the measurement of productive efficiency. Farrell further stated that the primary reason that all attempts to solve the problem had failed, was due to a failure to combine the measurements of the multiple inputs into any satisfactory measure of efficiency. These inadequate approaches included forming an average productivity for a single input (ignoring all other inputs), and constructing an index of efficiency in which a weighted average of inputs is compared with output. Responding to these inadequacies of separate indices of labor productivity, capital productivity, etc., Farrell proposed an activity analysis approach that could more adequately deal with the problem. His measures were intended to be applicable to any productive organization. Unfortunately, he confined his numerical examples and discussion to single output situations, although he was able to formulate a multiple output case.

Twenty years after Farrell's seminal work, and building on those ideas, Charnes et al. (1978), responding to the need for satisfactory procedures to assess the relative efficiencies of multi-input multi-output production units, introduced a powerful methodology which has subsequently been titled data envelopment analysis (DEA). The original idea behind DEA was to provide a methodology whereby, within a set of comparable decision making units (DMUs), those exhibiting best practice could be identified, and would form an efficient frontier. Furthermore, the methodology enables one to measure the level of efficiency of non-frontier units, and to identify benchmarks against which such inefficient units can be compared.

DEA has been recognized as an excellent method for analyzing performance and modeling organizations and operational processes, particularly when market prices are unavailable. The technique of DEA is non-parametric because it requires no assumption about the weights of the underlying production function. In other words, the statistical regression method estimates the parameters in the assumed functional form by a single optimization over all decision making units (DMUs) whereas DEA uses different optimizations (linear programming problems) for different DMUs without a priori assumptions on the underlying functional forms. It calculates a maximum performance measure for each DMU relative to all other units in the observed population.

Since the advent of DEA in 1978 (original CCR model), there has been an impressive growth both in theoretical developments and applications of the ideas to practical situations. Based on different empirical axioms and corresponding to different characteristics of the production possibility set and production frontiers, different DEA models, namely the BCC model, the FG model, the ST model, and the CCWH model, are developed and applied in practice.

The rest of the paper is organized as follows. Section 2 compares the CCR, BCC and FG models of DEA, section 3 analyzes scale efficiency of fishery production in Zhejiang province of China. Concluding remarks are made at the last section.

2. The Comparison of CCR, BCC and FG Models. Charnes, Cooper and Rhodes(1978) proposed a input-oriented model for efficiency estimation.

$$\begin{cases} \min \theta - \varepsilon(\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_r^-) \\ \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- - \theta x_{i0} = 0 \\ \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{r0} \\ i = 1, \cdots, m; \quad r = 1, \cdots, s \\ \lambda_j \geq 0, \quad j = 1, \cdots n \\ s_r^+ \geq 0, \quad s_i^- \geq 0 \end{cases} \tag{1}$$

Model（1）is referred to as the CCR model, which is a unique Envelopment form for the convenient to discuss and application of computation. Further, slack variables and surplus variables are drawn in the model.

Where θ denotes the technology efficiency of *decision making units* (DMU_0), $x_{ij}\left(i = 1, 2, \cdots m\right)$ is the inputs of $DMU_j\left(j = 1, 2, \cdots, n\right)$, y_{rj} (r = 1,. . ., s) is the outputs of DMU_j., slack variable s_r^+ equal to pure surplus in input, surplus variables s_i^- equal to pure lack in output.

The CCR model assumes that DMUs operate under the situation of constant returns to scale (CRS). In fact, the inefficiency of technology probably comes from the factor of scale, not only for improper deployment of input and output. Banker, Charnes and Cooper put forward a BCC model to measuring relative efficiency under the situation of different returns to scale. The BCC model differs from the CCR model is that it has the additional convexity constraint on the λ_j, namely $\sum_{j=1}^{n} \lambda_j = 1$. The CCR model finds each DMU's overall efficiency. The BCC model decomposes overall efficiency into pure technical efficiency and scale efficiency. Overall efficiency is basically a measure by which DMUs are evaluated for their performance relative to other DMUs. However, its value is influenced by scale efficiency, which quantifies the effect of the presence of variable returns to scale in the DMUs. Thus, pure technical efficiency is overall efficiency that has the effect of scale efficiency removed. The relationship among these forms of efficiency is given as follows:

Overall efficiency = [Pure technical efficiency] * [scale efficiency]

Generally speaking, the pure technical efficiency of BBC model is greater than technical efficiency of CCR model. If overall efficiency equal to pure technical efficiency, then the DMU's inefficiency is not due to the scale factor.

Under the assumption of CRS, a proportional change in all inputs results in a proportional change in output. However, a proportional change in all inputs may not be globally possible. If, for example, one or more inputs are fixed, quasi-fixed, or otherwise restricted, the production process may exhibit *decreasing returns to scale* (DRS). In such a case a proportional increase in all inputs will result in a less than proportional change in output—at least along a segment of the production function. Alternatively, if a proportional change in all inputs allows for a more efficient means of production and, thus, a greater than proportional change in output, then the production process exhibits *increasing returns to scale* (IRS) along that segment of the production function. The scale efficiency and returns to scale of a DMU have important economic implications. Namely a DMU not exhibiting CRS may be either too large or too small.

In order to measure scale inefficiency is due to operating at a point of IRS or DRS an additional DEA model with the constraint that the sum of the intensity variables, namely $\sum_{j=1}^{n} \lambda_j \leq 1$ is solved by Fare, and Grosskopf, which is referred to as the FG model.

If a DMU is operating at a point of scale inefficiency and technical efficiency for i th DMU under the model of FG is equal to the efficiency under the model of CCR, then scale inefficiency is due to IRS. if the Farrell input-oriented measure of technical efficiency for ith DMU under the model of FG is greater than the efficiency under the model of CCR, then scale inefficiency is due to DRS.

3. The Scale Efficiency of Fishery Production in Zhejiang Province. In the current study we employ the model CCR and BCC to examining the scale efficiency and returns to scale of fishery production of Zhejiang province in China for the period from 1999 to 2008. In order to keep the research consistency, we select the single output and four inputs .The single output is annual Total Value of Fishery Production (TVFP) which are measured in 100,000,000 RMB by the 1980 official prices. The four inputs of are Newly Added Fixed Assets (NAFA), which are measured in 10,000 RMB, Fishery Labour (FL), Inland Aquiculture Area(IAA) and Motor Fishing Vessels(MFV). They are published in the Yearbook of China Fishery Economy issued by the Chinese Statistical Bureau. The data are summarized in Table 1.

TABLE 1. The inputs and output data of fishery production

year	FL	MFV	IAA	NAFA	TVFP
1999	710660	59425	205323	252554.8	263.61
2000	761302	58168	207727	304210.3	206.12
2001	787423	56098	210763	332916.2	218.49
2002	806835	55836	212964	460328	124.63
2003	826248	55574	215164	509951	270.27
2004	794522	49707	205078	526376	373
2005	749220	48253	205205	507537	392.23
2006	751858	48253	211988	608326	421.8
2007	754495	50317	190190	648501	445.17
2008	808900	50204	308155	747712	442.24

Where the computer program, DEA of benchmarking package in R software, which adopts the nonparametric linear-programming techniques of Fare et al. (1994), was used to estimate technical efficiency scores of all DMUs under the input-oriented model of CCR, BCC and FG, The result of all DMUs under the input-oriented model of CCR, BCC and FG are presented in table 2.

TABLE 2. Technical efficiency of all DMUs under the model of CCR, BCC and FG

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
FG	1	0.9874	0.9973	0.9495	0.9343	0.9881	1	1	1	0.997
CCR	1	0.7076	0.7175	0.3336	0.6756	0.9307	1	0.9977	1	0.9957
BCC	1	0.9874	0.9973	0.9495	0.9343	0.9881	1	1	1	0.997

From the table2, we found the returns to scale of year 1999, 2005, 2007 is constant. It means that the fishery production scales of year 1999, 2005, 2007 is efficient. These three DMUs operate under the situation of *constant returns to scale*. The output only effect by input, the production scale not impact on the output. Meanwhile, we can found the efficiency scores of other DMUs under the input-oriented model of BCC and FG are equal and the efficiency scores of all DMUs under the FG greater than the efficiency scores of other DMUs under the CCR. It denotes that the fishery production scales of year 2000, 2001, 2002, 2003, 2004, 2006, 2008 is inefficient. The output of fishery production on year2000, 2001, 2002, 2003, 2004, 2006, 2008 not only effect by input, also effect by production scale. As well as if we increasing input, the output of fishery production is increasing greater than that under the situation of constant returns to scale.

We estimated overall efficiency scores of each DMU_s of fishery production under the assumption of constant returns to scale (TECRS) and pure technical efficiency under the assumption of *variables returns to scale* (TEVRS), which results in a measure of technical efficiency that is free of any scale inefficiency. More precisely, we set formulation as follows

$$SE = TECRS / TEVRS \tag{2}$$

From the above formula we presented the scale efficiency (SE) of year2000, 2001, 2002, 2003, 2004, 2006, 2008, which are 0.71663, 0.719442, 0.351343, 0.723108, 0.941909, 1, 0.997, 1, 0.998696. The comparison of these scale efficiencies is illustrated in Fig. 1.

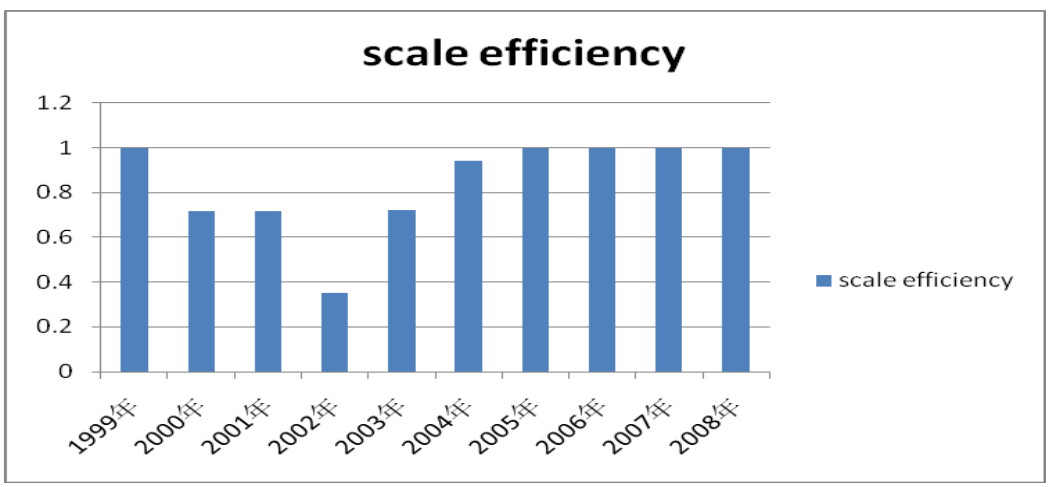

FIGURE 1. Scale efficiencies of all DMUs

It is clear from figure1, the scale efficiency of year2002 is the deeply lowest in all DMUs. So, we should expand fishery production scale of year 2002 in Zhejiang province and increase investment to fishery production. the results in Fig. 1 also show that the scale efficiency of year1999,2005,2006,2007, 2008 are nearly equals to unity, it implys the input of year1999,2005,2006,2007, 2008 relative to output have reached to high limit. The scale efficiency (or more precisely inefficiency) is part of the measure of technical efficiency (i.e. under the assumption of CRS), so the year of 2000, 2001, 2002, 2003, 2004 are operating at scale inefficiency. They should increase inputs to expand fishery production scale. More telling, because of scale inefficiency, based on the assumption of VRS, the year 2002's estimate of technical efficiency is 0.9495. Under the assumption of CRS, it drops to 0.3336, we should increase input to improve the scale efficiency to improve technical efficiency.

5. Conclusions. This paper has attempted to provide a brief sketch of some of the important areas of research in DEA since the appearance of the seminal Work of Charnes et al. (1978). The focus here is to compare the DEA models of CCR, BCC and FG and to give an application of these three DEA models. We explained the difference between the model CCR BBC and FG, and illustrated it by measuring the efficiency of fishery production of Zhejiang province in China. We found that the scale is nearly efficient at the year of 1999, 2005, 2006, 2007, 2008. The other years are inefficient. It is also found if the scale is inefficient, returns to scale of fishery production is increasing, which implys the industry should be increased input to improve efficiency.

As shown in the current paper, DEA can be used as a tool for measuring the scale efficiency change of the Chinese fishery industries whose industrial activities constitute important components of Chinese economic development planning efforts. The current study indicates that the scale efficiency does not always shift in a desirable direction (production improvement direction). This implies that the intertemporal changes in efficiency and technology are not steady during the Ten- year periods studied. This study provides information on the result of Chinese economic developing plans and in turn can improve the economic planning at different administrative levels in China. The comparison of DEA models developed in the current study is input-oriented. Similarly, we can develop an output-oriented DEA models for future work.

Acknowledgment. This paper is supported by the Open Foundation from Ocean Fishery Science and Technology in the Most Important Subjects of Zhejiang (No. 20100110).

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