ALTERNATIVE APPROACHES TO EVALUATING MULTISPECIES FISHERY EFFICIENCY

Gianluigi COPPOLA, University of Salerno, glcoppola@unisa.it
Monica GAMBINO, IREPA Onlus, gambino@irepa.org
Massimo SPAGNOLO University of Salerno and IREPA Onlus, spagnolo@irepa.org

ABSTRACT

In this paper, the estimate of the productive efficiency for some Italian fleet segments is proposed. The estimate is based on a Stochastic Frontier Production (SFP) function and a Data Envelopment Analysis frontier (DEA) using micro data of fishing vessels.
The essential random nature of the fishing processes under consideration suggests that stochastic method might be preferable to non-parametric DEA method for efficiency estimation. In other words, the risk connected with DEA is that random noise, probably due to exogenous shocks or measurement error, may be considered as inefficient. On the other hand, DEA does not identify an explicit functional form for the production function combined with a distributional form for the inefficiency term. Therefore, DEA should be less prone to mis-specification than Stochastic Frontier Production.
In fishery literature, several empirical comparisons between DEA and SFP have been conducted in order to assess the level of efficiency of fishing vessels and fleet segments. This paper attempts to apply both techniques, simultaneously, to the Mediterranean area which is characterised by multi-species and artisanal-type fishery.

Keywords: Technical efficiency, Stochastic Frontier Production, Data Envelopment Analysis

INTRODUCTION

In fisheries economics, many studies that applied Stochastic Frontier Productions and/or Data Envelopment Analysis have been conducted in order to assess the efficiency of fleets. Despite the growing development of such studies, empirical application of these two methodologies to the Mediterranean is rare. Within the present study, the stochastic frontier approach and the Data Envelopment Analysis are applied to two main Italian fishing activities: namely, trawl fishery and small-scale fishery. With a view to evaluating the applicability of such techniques to these two typical multi-species activities, we try to examine the factors than might affect the outcomes of these analyses.
Italian fishery is characterised by the presence of both industrial and artisanal fisheries, whose fishing techniques compete by simultaneously exploiting multi-species stocks. Therefore, in order to evaluate the ability of these models to correctly identify relative efficiency, a comparative analysis between the efficiency of trawlers and small-scale vessels may represent a significant analytical starting point. Even though the trawl fleet varies in size and productivity, its activity is homogenously performed along the Italian coats. On the contrary, the activity and the structure of the small-scale fleet are closely related to the different local traditions, which affect the type of gears used and the type of resources targeted. Weather conditions and seabed morphology also influence the variability of their fishing activities.
The present study examines two coastal areas: the Central and Northern Adriatic Sea (FAO/GFCM geographical sub-area, GSA 17) and the Tyrrhenian area, identified by the Ligurian, Tyrrhenian and Sardinia Seas (GSA 9-10-11) that, in terms of echo-system, can be considered as homogeneous. A large number of species live in these ecosystems, whose economic importance varies from area to area. Indeed, thanks to its wide continental shelf and shallow waters, the Central and Northern Adriatic Sea show higher natural and fishing productivity than the Tyrrhenian Sea.
The paper is structured as follows: models and data sets are described after a brief presentation of the case studies, whereas the empirical applications of SPF and DEA are followed by a discussion on the implications of their results.

THE CASE STUDIES

Trawlers

The Italian trawl fleet target several species of which European hake, red mullets, common and horned octopuses, shrimps and Norway lobster are the most important ones. In 2003, the group of other fish (finfishes and demersal fishes) accounted for 50% of the overall landings, followed by marine crustaceans (34%) and molluscs (16%). This fleet segment accounts for 28% of the total national catches (86,234 tonnes) and 38% of the total value of landings (558 million euro). In terms of both value and volume, the Central and Northern Adriatic fleet represents 29% of the national production of trawlers. The Tyrrhenian area accounts for 18% of national trawl production in volume and 22% in value.

This fleet segment includes two gears: bottom otter trawl and beam trawl. In 2003, it consisted of 2,507 vessels, that is, 16.2% of the national fleet. On average, its vessels have a tonnage of 39 GRT, a crew of 3.8 men and 188 days spent at sea (IREPA, 2003).

Trawling fishery is governed by two main typologies of regulations, which impose the following set of restrictions: a minimum mesh size of 40 mm and a ban on trawling within 3 nautical miles of the coast or, where this depth is reached at a shorter distance, within the 50m isobath, (EC Regulation 1626/1994). In particular, the latter restriction represents a source of conflict within small-scale fisheries. In fact, given that the Mediterranean (apart from the Adriatic Sea) is characterized by a narrow continental shelf, about 90 per cent of the fishing within the area is considered as coastal. This entails that this type of fishing activity is often performed inshore. Thus it deprives small-scale fisheries of their catches and, furthermore, it heavily affects nurseries and spawning grounds.

Over the last four years, the buyback program under the MAGP IV reduced this fleet segment by 16% in terms of both number of vessels and GRT. Italian trawlers are also subject to a measure of temporary withdrawal, which is optional within the Tyrrhenian Sea but compulsory within the Adriatic. The temporary withdrawal plan is established from year to year by taking into account the spawning season. Within the Adriatic Sea, fishery is usually suspended from mid-July to mid-August, while within the Tyrrhenian the temporary halt extends from mid-September to mid-October.

Small-scale fishery

That of small-scale fishery is the Italian fleet segment with the greatest number of vessels. In 2003, in fact, it accounted for almost 53% of national fleet. The segment includes vessels not exceeding 12 metres in length, which use passive gears (mainly fixed nets, pots, traps) and operate within 12 miles of the coast. The average size of these vessels is 2.6 GRT and 25 kW, while the average size of the national fleet is 11 GRT and 79 kW. Small-scale vessels are older than other segments of the fleet, 28 years old, on average. Therefore small-scale vessel segments, with their average age of 28 years, are the eldest of the fleet. Fishermen represent 50% of national total with an average crew of 2 men.

Small-scale fisheries segment accounts for 16% of the national catch and 23% of national value of landings. In 2003, the group of other fish (finfish and demersals) represented 65% of total landing, followed by molluscs (27%) and marine crustaceans (3%).

Small-scale fishery registers low capital intensity and is deeply affected by weather conditions and market fluctuations. Average income is low, but these vessels represent an important economic resource in some geographical areas strictly dependent on fishery. However, the economic performance of small-scale vessels is very different from area to area. Within the Adriatic, both landings and value per effort are higher than in other regions. This is due to various factors, such as the lowest level of fishing effort and differences in landing mix, which is mainly composed by crustaceans (mainly Changeable nassa) and molluscs (mainly horned octopuses and carpet shells). Within Tyrrhenian areas, on the contrary, over 80% of landings (both in terms of weight and value) are composed by fish (European hake and red mullets).

Over the last few years, this fleet segment has also undergone a huge reduction in the overall capacity and economic indicators. Over the period 1998-2002, the decommissioning scheme under the MAGP IV led to a reduction of 18% in total GRT and of more than 2 thousand units (-24%) in the total number of vessels.

METHODOLOGY

The technical efficiency (TE) of a firm can be defined as the ability of a firm to obtain maximal output from a given set of input (Farrell, 1957). It is commonly measured in terms of deviations of observed output from the best production or efficient production functions. Once defined the production frontier of the fully efficient firms, the technical efficiency of firm is given by the ratio between its actual production and the potential production. A TE ratio of 1 indicates the firm is fully technically efficient because it lies on the efficient isoquant. A TE ratio lower than 1 implies that the firm lies below the frontier and then it is technically inefficient.

The efficient production frontier is commonly estimated using two quantitative approaches: the Stochastic Production Frontier (SPF) and the Data Envelopment Analysis (DEA). The choice of the appropriate method should depend on a careful weighting of many factors. The essential random nature of the fishing processes under consideration suggests that stochastic method might be preferable to non-parametric DEA method for efficiency estimation. In other words, the risk connected with DEA is that random noise, probably due to exogenous shocks or measurement error, may be considered as inefficient. And this could be a problem if random variation in output rates are significant (Ward, 2000). On the other hand, DEA is less prone to mis-specification than Stochastic Frontier Production since it doesn't require an explicit functional form for the production function and for the inefficiency term. This aspect is not of secondary importance in multi-purpose fishing fleets, where the specification of single production function for all units could be not appropriate (Pascoe and Tingley, 2002). Furthermore, DEA respect to SPF easily accommodates multiple outputs and multiple inputs (Färe at al, 2000). As a results, it offers a convenient framework for analyzing the efficiency in multi-species fisheries because it does not require prior aggregation of the outputs.

Stochastic Production Frontier

The stochastic production frontier approach is well known since the articles of Aigner, Lovell and Smith (1977) and Meeussen and van den Broeck (1977). More recently this approach has been applied in fisheries economics (among others Pascoe et al, 1998). The basic idea is to consider the relationship between catch and effort, firstly considered as biological one, as production function where the inputs are the component of the effort and the output is the yield.

Given a production function for several firms i that produce at different times t:

$$Y_{it} = f(x_{it}, \beta) \quad \text{(eq. 1)}$$

where Y is the output, x_i the vector of the inputs and β the parameters to estimate, a stochastic production function is obtained by introducing in the formula, the level of efficiency ξ_{it} for the single firm at the time t:

$$Y_{it} = f(x_{it}, \beta)\, \xi_{it} \quad \text{(eq. 2)}$$

ξ_{it} is the fundamental element of stochastic production function and it measures the level of efficiency for the firm i at the time t. The presence of ξ_{it} in the formula implies the possibility that the firm may not achieve the maximum yield obtainable by the technology embodied in the production function. ξ_{it} varies in the interval between 0 and 1. The value 1 means the maximum level of efficiency, while when ξ_{it} tends to zero the level of inefficiency grows. Adding the random term $v_{it} \approx N(0,\sigma^2_v)$ normally distributed, the equation becomes

$$Y_{it} = f(x_{it}, \beta)\, \xi_{it}\, v_{it} \quad \text{(eq. 3)}$$

Let's assume that $u_{i\,t} = -\ln(\xi_{it})$ where $u_{it} \approx N(\mu,\sigma^2_\mu)$ is a truncated normal distribution, being $0 < \xi_{it} \leq 1$.

Taking the natural log of both sides, the following formula is obtained:

$$\ln(Y_{it}) = \ln[f(x_{it}, \beta)] + v_{it} - u_{it} \quad \text{(eq. 4)}$$

If the production function is a Cobb Douglas, it becomes:

$$\ln(Y_{it}) = \beta_0 + \beta_q \sum_j \beta_q \ln x_{jit} + v_{it} - u_{it} \qquad \text{(eq. 5)}$$

The term u_{it}, measures the inefficiency effect and may be assumed to be constant, or time-varying. In this last case u_{it} is assumed to vary according the formula:

$$u_{it} = \exp\{-\eta\,(t-T_i)\,u_i\} \qquad \text{(eq. 6)}$$

For $\eta > 0$ the degree of inefficiency decreases, for $\eta < 0$ it increases while for $\eta = 0$ the inefficiency is constant and the model is time invariant.

Data Envelopment Analysis

Unlike the SPF model, DEA can be considered an approach rather than a model (FAO, 2003). It simply consists in a linear programming technique for considering optimum solutions relative to individual units. The purpose of DEA is to construct a non parametric envelopment frontier over the data points, such that all observed points lie on or below the production frontier. DEA measures efficiency by comparing each individual production unit against all other production units within its sample data. The efficiency of each unit is calculated by comparing output and input use with points on the production frontier (best observed practice). If the production unit is on the frontier (efficient point), it will be assigned an efficiency score of 1. On the contrary, if a unit is inside the frontier (inefficient point) it will be assigned an efficiency score smaller than 1.

The output oriented DEA model for technically efficient measure of output is given as (Pascoe and Tingley, 2002):

$$\text{Max } \theta$$

s.t.

$$\theta\, u_{0,m} \le \sum_j z_j u_{j,m} \quad \forall m$$

$$\sum_j z_j x_{j,n} \le x_{0,n} \quad \forall n$$

$$\sum_j z_j = 1$$

$$z_j \ge 0$$

(Eq. 7)

where:

θ is a scalar outcome showing how much the production of each firm can increase by using inputs (both fixed and variable) in a technically efficient configuration.

$u_{j,m}$ is the output m produced by boat j,

$x_{j,n}$ is the amount of input n used by boat j

z_j are weighting factors measuring the distance of boat j is from the frontier.

The value of θ is estimated for each vessel separately, with the target vessel's outputs and inputs being denoted by $u_{0,m}$ and $x_{0,n}$ respectively. Inputs include both fixed and variable factors, which are constrained to their current levels. The restriction $\Sigma z_j = 1$ allows for variable returns to scale.

From this, technical efficiency (TE) is estimated as:

$$TE = 1/\theta \qquad \text{(Eq. 8)}$$

It represents the extent to which output can increase through using all inputs efficiently.

DATA

Data used in this study are produced by IREPA, which since 1985 carries out a sample survey of Italian fishery sector. The IREPA National Observatory collects all technical and administrative information of vessel, relevant socio-economic aspects (number of ship owners, their ages, their property quotas and relationships between them), data on fixed and variable costs and on activity such as fishing time and area, average number of crewmembers, gears used, quantities, prices and revenues – as per species or group of species – and distribution channel for sales.

For each case study a panel of monthly observations was available, covering a period of four years from 2000 to 2003. A total of 33 trawlers and 21 small scale vessels were selected for the Tyrrhenian area. For the Adriatic area, the data sets were composed of 29 trawlers and 13 small-scale vessels. The characteristics of data sets are presented in table I.

Table I: Characteristics of data sets for case studies

	No of vessels	No of observations
Tyrrhenian trawlers	33	1473
Central & Northern Adriatic trawlers	29	1272
Tyrrhenian small scale vessels	21	956
Central & Northern Adriatic small scale vessels	13	561

The estimation of technical efficiency using a stochastic production frontier requires aggregated outputs. For this reason, total landings in volume were considered as output. The key inputs were gross registered tonnage (GRT), length overall (LOA), engine power (kW) as fixed inputs, and days fished and number of crew as variable inputs. The correlation matrix and some statistics of variables are presented in table II.

Central and Northern Adriatic trawlers have on average higher economic and physical indicators higher than Tyrrhenian trawlers, although the Adriatic trawl fleet shows on average three days less a month than the Tyrrhenian trawl fleet. As previously specified, this is due to the different application of the regulation related to the temporary withdrawal in the two areas. Also the Northern Adriatic small scale vessels have on average physical and economic characteristics higher than Tyrrhenian small scale fleet. The only exception is the average tonnage, that is equal to 4.28 GRT for the Tyrrhenian vessels against an average tonnage of 2.57 for the Adriatic boats.

Some variables are highly correlated among them, such as GRT, LOA and kW. For this reason in the estimation analysis they were considered separately in order to avoid multicollinearity problems.

Among explanatory variables the size of the stock wasn't included. Given the multi-specificity of fisheries investigated, it was quite difficult to estimate an aggregated index representing stock abundance. To encompass this problem, we treated stock (and time) as a categorical variable assuming that boats operating in the same time period (month) are subject to the same stock conditions. This means that in DEA models only boats that operate in the same months were compared. In SPF models, the effect of seasonal variation in stock was considered through the inclusion of monthly dummy variables (Coglan at al, 1998)

Table II: Correlation matrix and summary statistics of variables for case studies (2000-2003)

	GRT	LOA	kW	Days	No crew	Days*crew	Volume (tons)
Tyrrhenian trawlers							
GRT	1.00	0.96	0.59	0.13	0.75	0.57	0.36
LOA		1.00	0.64	0.10	0.69	0.50	0.39
kW			1.00	0.02	0.42	0.25	0.39
Days				1.00	0.03	0.73	0.38
No crew					1.00	0.67	0.34
Days*crew						1.00	0.49
Volume (tons)							1.00
Mean	39.33	19.50	228.68	16.17	3.16	51.16	2.31
Std.Dev.	21.11	4.06	101.06	4.65	0.92	21.75	1.42
Central & Northern Adriatic trawlers							
GRT	1.00	0.92	0.63	0.09	0.68	0.52	0.34
LOA		1.00	0.68	0.10	0.78	0.58	0.39
kW			1.00	0.21	0.61	0.56	0.52
Days				1.00	0.16	0.71	0.37
No crew					1.00	0.79	0.36
Days*crew						1.00	0.49
Volume (tons)							1.00
Mean	46.41	20.81	259.96	13.96	3.95	56.01	4.05
Std.Dev.	27.67	3.96	119.00	3.91	1.30	26.15	3.77
Tyrrhenian small scale vessels							
GRT	1.00	0.92	0.66	-0.20	0.07	-0.10	0.06
LOA		1.00	0.65	-0.24	0.14	-0.04	0.09
kW			1.00	-0.30	0.01	-0.18	0.16
Days				1.00	0.09	0.56	0.13
No crew					1.00	0.85	0.20
Days*crew						1.00	0.23
Volume (tons)							1.00
Mean	4.28	8.07	41.38	12.99	1.77	23.51	0.56
Std.Dev.	2.21	1.63	32.96	5.86	1.04	19.15	0.61
Central & Northern Adriatic small scale vessels							
GRT	1.00	0.54	0.61	-0.26	0.10	-0.09	0.07
LOA		1.00	-0.05	-0.04	0.53	0.24	-0.09
kW			1.00	-0.19	-0.46	-0.35	0.32
Days				1.00	0.25	0.81	0.36
No crew					1.00	0.73	-0.03
Days*crew						1.00	0.21
Volume (tons)							1.00
Mean	2.57	7.70	55.42	14.30	1.51	22.30	0.84
Std.Dev.	0.88	1.21	41.46	5.59	0.50	12.65	0.86

RESULTS

The SPF results

The stochastic frontier model estimated by the Maximum likelihood method is a Cobb Douglas function[i]:

$$Y = A\ GRT^{\alpha 1} * kW^{\alpha 2} * Crew^{\alpha 3} * Days^{\alpha 4} * \text{Monthly dummies}\ ^{\alpha D1\text{-}11}\ e^{u} * e^{v} \text{(Eq. 9)}$$

where Y is the output, A is a constant, GRT the Gross Register Tonnage, kW the fishing power in kilowatt, Crew the number of crew member, Days the fishing days. α_1, α_2, α_3, α_4, are the elasticities of the respective factors. Monthly dummies were also included in order to take into account the seasonal effects. In some cases it has been used the variable crew per day (Crew*days), assuming the same elasticity for both variables. The stochastic terms u e v are respectively the level of inefficiency and the idiosyncratic error.

Besides the coefficient, the output of STATA 8 reports estimates for the parameters σ^2_v, σ^2_u and $\sigma^2=\sigma^2_v+\sigma^2_u$. σ^2_v is the variance of he inefficient term, σ^2_u is the variance of the idiosyncratic error and σ^2 is the total variance. The parameter γ is the estimate of $\gamma = \sigma^2_u / \sigma^2$. It measures the ratio of the total variance due to the inefficient term. Since γ varies between 0 and 1, the optimization is parameterized in terms of logit of γ.

The Maximum-likelihood estimates of the 4 models are presented in table III.

Table III: Parameter estimates of Stochastic Production Frontier Models

	Tyrrhenian Trawlers (model I)		Tyrrhenian small scale ves. (model II)		C&N Adriatic trawlers (model III)		C&N Adriatic small scale ves. (model IV)	
	Coeff.	T-ratio	Coeff.	T-ratio	Coeff.	T-ratio	Coeff.	T-ratio
Constant	-0.83	-9.80	0.54	1.73	0.63	2.87	-0.35	-1.06
lnGRT	0.23	4.23						
lnkW			0.44	2.23	0.26	2.09	0.75	3.39
lnDAYS	0.92	37.47	1.02	25.42				
lncrew*lnday					0.98	28.14	1.16	20.18
January					-0.07	-2.84		
February					-0.10	-4.17		
March					-0.11	-4.61		
April					-0.11	-4.59		
May					-0.11	-4.86		
June					-0.11	-4.90		
July					-0.14	-5.87		
August					-0.05	-1.76		
September					0.06	2.49		
October					0.02	0.71		
November					0.01	0.37		
μ	0.26	2.78	0.69	5.25	0.26	1.81	0.62	2.99
$\ln(\sigma^2)$	-2.47	-7.05	-1.91	-8.54	-2.84	-11.26	-1.93	-8.84
$(\text{logit}\ \gamma)^{-1}$	1.28	2.83	0.48	1.32	-0.04	-0.07	-1.16	-0.35
η					-0.01	-3.09		
σ^2	0.08		0.15		0.06		0.15	
γ	0.78		0.62		0.49		0.46	
σ^2_u	0.07		0.09		0.03		0.07	
σ^2_v	0.02		0.06		0.03		0.08	
Log Likelihood	777.12		-28.67		388.96		-106.36	
CRS test	6.94		5.09		3.75		15.20	
	(0.0084)		(0.0241)		(0.0528)		(0.0001)	

Despite the high number of models estimated, it's possible to highlight some recurring evidence:

1. The estimate of the inefficiency effect's mean (μ) is always highly significative except for the model III (C&N Adriatic trawlers) where the significance is at 10%.
2. The importance of the inefficient term γ varies between 0.46 (model IV) and 0.78 (model I).
3. The monthly dummies are significative and present only in the model III relative to the Central and Northern Adriatic trawlers.
4. Again, only for model III time variant (η) is relevant and negative. It means that inefficiency increases only for the Central and Northern Adriatic trawlers, according the dynamic of inefficiency effect u_{it} while for the other cases is constant.
5. Returns to scale are constant if the CRS test is not significative. In this case, only models II (Tyrrhenian small scale vessels) and III show constant returns to scale. All other models, given the significance at 1% of CRS test, show increasing returns to scale.
6. For all models, the elasticities of variable inputs (days or crew*days) are larger than elasticities of fixed inputs (GRT or kW).

DEA results

DEA results were produced using a GAMS (General Algebraic Modelling System) program developed by Sean Pascoe. It was run separately for the four fleets and for each month (Pascoe, 2000). First, to allow for a direct comparison of results, the single output measure and the same inputs of the SPF models were considered. In a second stage, DEA also run with all outputs together (main groups of species), in order to reduce the influence of random fluctuations on the comparative process and provide a more accurate estimate of technical efficiency.

As would be expected, the levels of technical efficiency estimated using the DEA multiple output measures (DEA2 scores) are considerably higher than DEA single output based estimates (DEA1 scores). The results of both DEA models are presented in the following pages.

The comparison of results

The average technical efficiency scores produced by DEA and SPF and their correlations are presented in table III. The results are subdivided by case study and inputs considered in the analysis.

First, for each case study the stochastic frontier production was estimated, in order to suggest which inputs to employ in the following DEA analysis. Thus far, the same variables were used in both analyses.

Table III: DEA and SPF results

	Inputs	Average TE scores 2000-2003			Correlation (average vessel scores)		
		DEA1	DEA2	SPF	DEA1/ SPF	DEA2/ SPF	DEA1/ DEA2
Tyrrhenian trawlers	GRT-days	0.48	0.64	0.73	0.78	0.69	0.94
Tyrrhenian small scale ves.	kW -days	0.49	0.62	0.52	0.82	0.79	0.95
C&N Adriatic trawlers	kW-No Crew*days	0.59	0.78	0.80	0.80	0.81	0.90
C&N Adriatic small scale ves.	kW - No Crew *days	0.65	0.82	0.55	0.73	0.67	0.87

Despite the high correlation between DEA1 and SPF scores, the technical efficient scores varies considerably among methods and case studies. The DEA1 scores are generally smaller than the corresponding SPF scores. The DEA2 scores, even if higher, highlight a pattern similar to DEA1 scores.

For small scale vessels DEA2 estimates of technical efficiency are always greater than SPF scores. For the trawl fleets, the relation between DEA2 and SPF scores is inverted.

For all methods, the level of efficiency estimated for the Adriatic area are always greater than those related to the Tyrrhenian area. For both areas investigated, SPF found that trawlers have average technical efficiency higher than small scale vessels. On contrary, the level of efficiency estimated by DEA for the Adriatic trawlers is less than technical efficiency estimated for Adriatic small scale fleet.
The highest mean efficiency was estimated to 0.80 for SPF (Central and Northern Adriatic trawlers) and to 0.82 (Central and Northern Adriatic small scale fleet) for DEA2.
The differences between these estimates could be explained by different reasons. Probably the random noise in output data could create bias estimates in DEA results. This bias also could have increased with fleet size and the number of observations (Lee and Holland, 2000). In Tab IV we compare the differences between SPF and DEA scores with the levels of random variations and the number of observation. The effect of random variations in output are measured by the variance of the idiosyncratic error σ^2_u, the variance of he inefficient term σ^2_v, the total variance σ^2 and by the parameter $\gamma = \sigma^2_u / \sigma^2$.

Table IV: Levels of Random Variation, Number of observations and Differences between SPF and DEA scores.

	Output	σ^2_u	σ^2_v	σ^2	γ	No obs	SPF-DEA1	SPF-DEA2
Tyrrhenian trawlers	catch	0.07	0.02	0.08	0.78	1473	0.25	0.09
Tyrrhenian small scale ves.	catch	0.09	0.06	0.15	0.62	956	0.03	-0.10
C&N Adriatic trawlers	catch	0.03	0.03	0.06	0.49	1272	0.21	0.02
C&N Adriatic small scale ves.	catch	0.07	0.08	0.15	0.46	561	-0.10	-0.27

The comparison with the variance estimates didn't highlight any particular evidence. Probably this is due to the fact that all case studies present a similar level of random error. On the contrary, a relation was found with the number of observations. In Figure 1 are depicted the number of observations and differences between SPF and DEA1 scores. They show the same trend. More precisely, the positive difference between SPF and DEA1 average scores increases with the dimension of the sample.

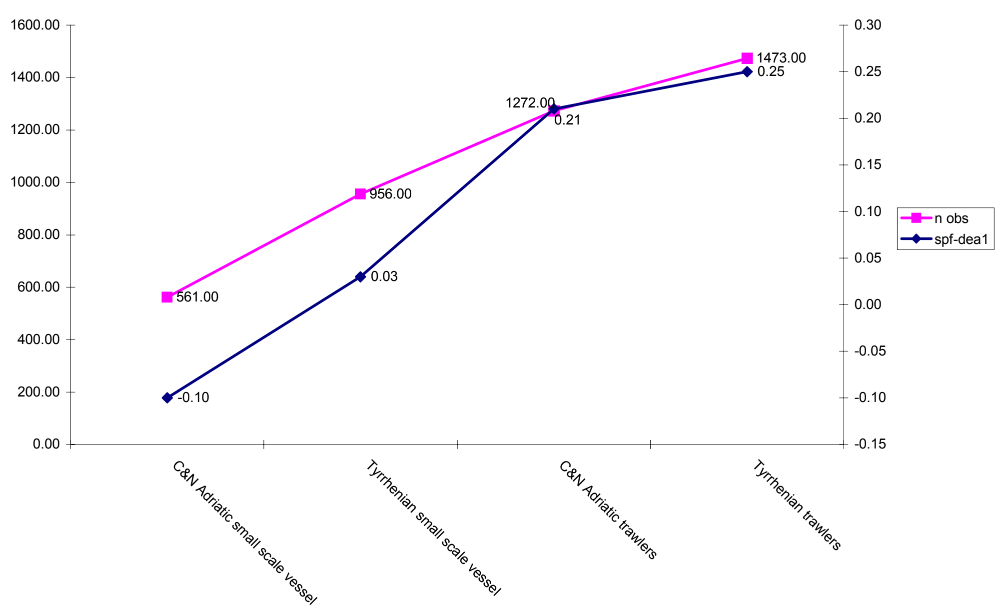

Figure 1. Number of observations and differences between SPF and DEA1 scores

The Figure 2 show the average technical efficiency for each boat. The DEA1 scores are ordered from lowest to highest. Under DEA1 approach, the production is technical efficient for few observations. For some units of the Tyrrhenian small scale fleet, DEA1 estimates a level of efficiency close to 10%. Under SPF approach, the production is efficient for considerably more observations. Only in some cases, the two methods give identical results. For most observations, the levels of technical efficiency estimated vary considerably between SPF and DEA.

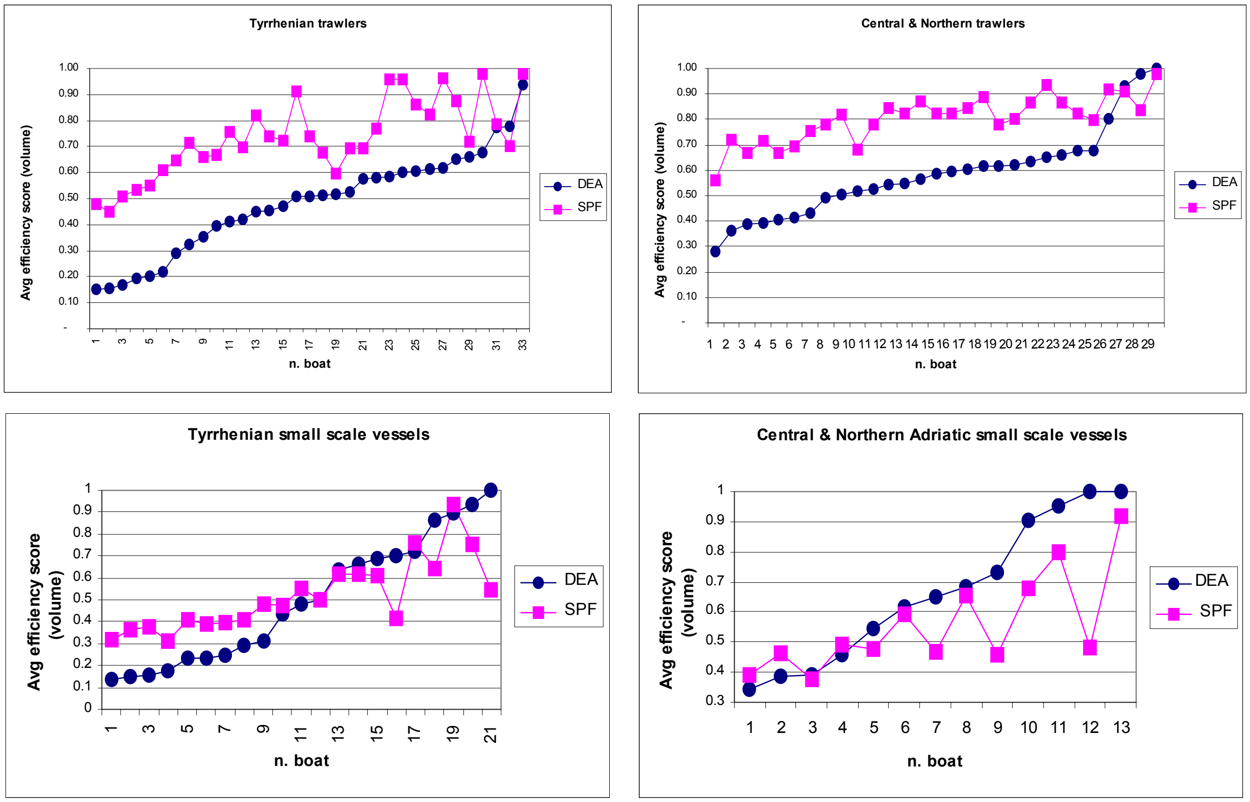

Figure 2. Average efficiency estimates for boats

The frequency distribution of TE results are finally depicted in Figure 3. From this, it can be seen that SPF technical efficiency average scores are concentrated in few classes: the trawl fleet is more concentrated at high classes, the small scale fleet at low classes. For example, for Central and Northern Adriatic, about 45% of observations related to trawl fleet is in the range of 0.80-0.89 while about the 60% of observations related to small scale vessels is in the range 0.30-0.39. On contrary, DEA scores are generally distributed in more classes.

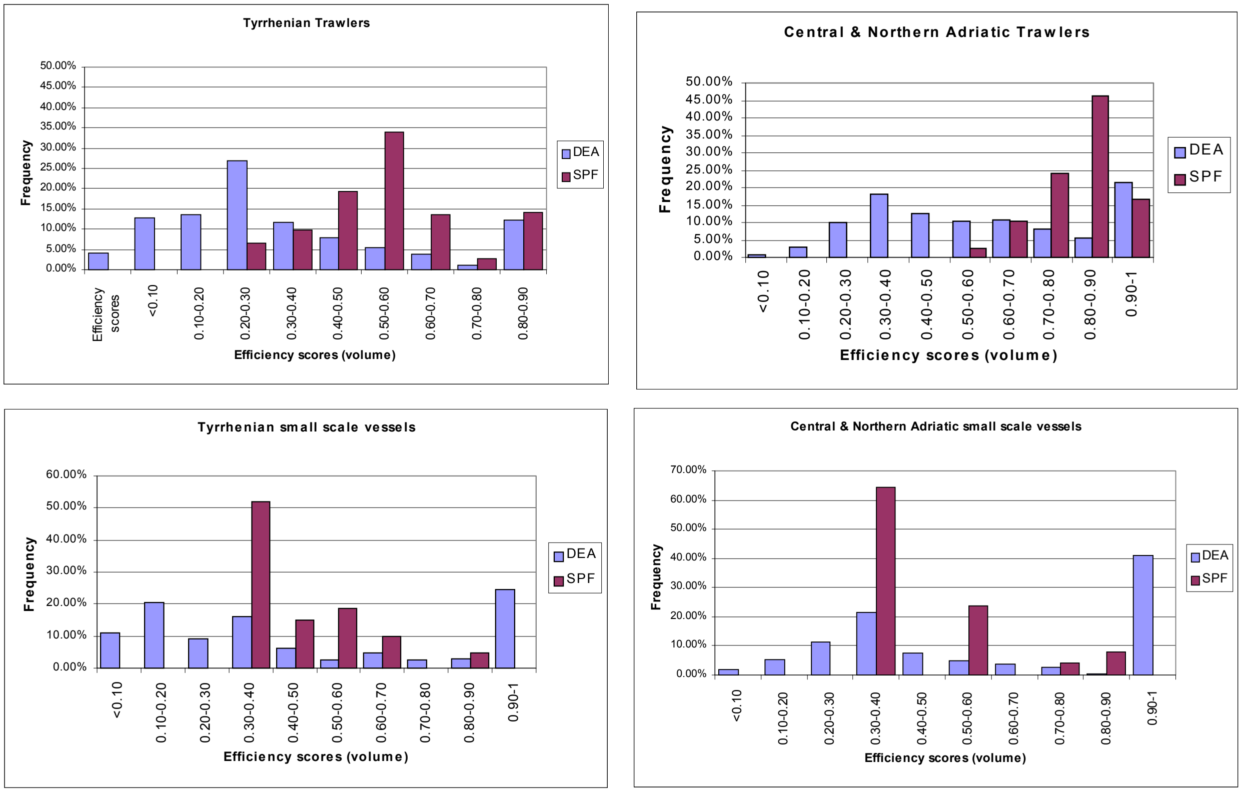

Figure 3. Distribution of efficiency estimates

DISCUSSIONS AND CONCLUSIONS

The empirical outcomes of this study suggest two kinds of considerations:, the first related to the applicability of SPF and DEA to Mediterranean fisheries and the second associated with the achieved results.

As widely evidenced in literature, this empirical analysis confirms there is a systematic difference in the results of these two approaches(Lee and Holland, 2000). The analysis allow to confirm the pervious evidence even when the DEA technique is improved through a multiple output measure of technical efficiency (DEA2 scores). The comparative analysis with the random error and the number of observations prove that the differences between SPF and DEA scores increase with the sample dimension. The maximum levels of technical efficiency predicted by these two methods approximate 80% for the Adriatic and 70% for the Tyrrhenian area. Most likely, the inclusion of other qualitative factors, such as those concerning the skipper's ability, might have increased the levels of estimated efficiency.

A first conclusion of this study suggests that a direct comparison between SPF and DEA, which uses a single output measure of DEA, is difficult to apply to the Mediterranean case, where the strong multispecificity has a great influence on random variations.

Another result is associated with multiple output measure of DEA (DEA2 scores). The DEA2 estimates of technical efficiency are always higher than SPF scores for small-scale vessels. By contrast, SPF scores are always higher than DEA scores for trawlers. These outcomes suggest that the DEA approach is more suitable to identify efficiency when the fleet considered is heterogeneous and varies in economic performance. On the contrary, by requiring a unique functional form for the production function and for the inefficient term, the stochastic production frontier proves to be more appropriate for homogenous fleet segment as the trawl fleet.

In conclusion, from the study it emerges that for multi-species fisheries, the choice between DEA and SPF techniques depends not only on the random nature of fishing processes, but also on the characteristics of their activity. SPF approach proved more appropriated when the fishing activity is particularly homogenous. Conversely, if the operational characteristics of a fleet vary from a vessel to another, DEA approach is likely to predict better estimates of technical efficiency.

REFERENCES

Aigner, D., C.A.K Lovell and P Schmidt, 1977, Formulation and estimation of stochastic frontier production function models, *Journal of Econometrics, 6*, pp. 21-37.

Battese, G.E. and T.J. Coelli, 1992. Frontier Production Function, technical efficiency and panel data: with application to Paddy Farmers in India, *J. Productiv. Anal., 3*, pp. 153-169.

Coelli, T., D.S. Prasada Rao and G.E. Battese, 1998, An Introduction to Efficiency and Productivity Analysis, *Dordrecht: Kluver Academic Publishes*.

Coglan, L., Pascoe, S. and R. Harris. 1998, Measuring efficiency in demersal trawlers using a frontier production function approach, *Proceedings of the X Annual EAFE Conference. The Hague. The Netherlands.*

Färe, Rolf, Shawna Grosskopf and Dale Squires (2000), Data Envelopment Analysis (DEA): A Framework for Assessing Capacity in Fisheries When Data are Limited, *10th Biennal IIFET Conference, Corvallis, Oregon, USA.*

Farrell, M.J. 1957, The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society, series A, CXX, Part 3*, pp. 253-290.

FAO, 2003, Measuring and assessing capacity in fisheries 2. Issues and methods*, Fisheries Technical Papers 433(2),* pp. 129-150.

IREPA, 2003, Osservatorio economico sulle strutture produttive della pesca marittima in Italia 2001-2002, *XI Rapporto, Collana Irepa Ricerche*, FrancoAngeli ed. Milano.

Lee, Todd S. and Daniel Holland, 2000 , The impact of Noisy Catch data on estimates of efficient output derived from DEA and Stochastic Frontier Models: a Monte Carlo Comparison, *10th Biennal IIFET Conference, Corvallis, Oregon, USA*

Meeussen, W and J. van den Broeck, 1977, Efficiency Estimations from Cobb-Douglas Production Functions with Composed Error Terms, *International Economic Review Vol. 18, (June)*, pp 435-44.

Pascoe, S., Coglan, L., and S. Mardle, 2000, Physical versus harvest based measure of capacity: the case of the UK vessel capacity unit system, *10th Biennal IIFET Conference, Corvallis, Oregon, USA.*

Pascoe, S. and D. Tingley, 2002, Factors Affecting Technical Efficiency in Fisheries: Stochastic Production Frontier 'v' Data Envelopment Analysis approaches, *11th Biennal IIFET Conference, Wellington, New Zealand.*

Ward, John, (2000), Capacity, Excess Capacity, and Fisheries Management, *10th Biennal IIFET Conference, Corvallis, Oregon, USA.*

ENDNOTES

---

[i]The translog formulations have also been estimated but the null hypothesis of Cobb Douglas specification has been accepted. For sake of sintesys, the results are not reported in this paper.