Efficiency analysis of the Portuguese beam trawl fleet that targets the common prawn *Palaemon serratus* (Pennant).

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ABSTRACT

This paper focuses on the beam trawl fleet that operates in the centre-north of Portugal, and aims to estimate the technical efficiency of this in 2004 and to assess the technical efficiency change, the technical change of production technology and total factor productivity change for the period ranging from 1995 to 2004. The efficiency of the beam trawl fleet in 2004 was estimated, with parametric methods. To obtain the frontier form of production possibilities, we used the Stochastic Frontier Analysis (SFA) Technique. The evolution of efficiency was based in non-parametric methods namely the Malmquist Index, which is based on Data Envelopment Analysis (DEA) techniques. The results indicated that the technical efficiency of the Portuguese beam trawl fleet was relatively low. It was observed that the output depends positively and significantly of the engine power and the number of days at sea. The results showed a slightly decrease in the total factors productivity. This is a symptom of some inefficiency of the artisanal fishing sector, which has a greater role in social terms than in the economic ones. Technical efficiency grew slightly between 1995 and 2004, whereas technological change decreased, indicating that the beam trawl fleet had technological losses during the studied period. The conjugated effect of these two measures lead to a small decrease of the total factors productivity.

Key words: Beam trawl; Artisanal fleet; Technical Efficiency; Malmquist Index; Stochastic Frontier Analysis.

JEL Classification: Q22, D24, C21, C61

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1. INTRODUCTION

Portugal has a very important artisanal fishing sector, not only by its contribution to the local and regional economies but also because it represents a way to understand life as being able to retain one culture based on extraction, in responsible fishing, with an obligation to keep resources. Artisanal fisheries are carried out in coastal lagoons, estuaries and coastal waters mostly within the 12 mile zone. The Portuguese artisanal fleet represents about 81% of the total national fleet and employs around 18000 fishermen (DGPA, 1999).

Along the west coast of Portugal, the common prawn *Palaemon serratus* is one of the most important commercial species. This species live in shallow water from the intertidal zone to 60 m depth. In the Central-North of the west coast of Portugal, the common prawn is the target of an important artisanal beam trawl fishery. In 2004 a total of 111 boats were involved in this fishery. These boats varied in length from 4 to 12 m, with engines of 62±17 Hp. Despite the importance of this fishery, the technical efficiency of the common prawn beam trawl fishery was not hitherto analysed. Farrell (1957) proposed that the economic efficiency of a firm consists of two components: technical efficiency and allocative efficiency. The technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs. A firm is inefficient when it is technically possible to increase their output without needing to increase the inputs or produce the same output using fewer inputs. The allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and technology of production. The efficiency is calculated, using both parametric and non-parametric methods. With parametric methods, based on statistical concepts, we need to determine in advance the frontier form of production possibilities. The most used technique is the Stochastic Frontier Analysis (SFA). This technique has the advantages of being stochastic and it allows the testing of hypotheses. However, has the disadvantages of requiring the specification of production technology (e.g. Cobb-Douglas or Translog) and cannot be used for multiple outputs. The non-parametric methods are based on mathematical programming and it does not need to specify the production frontier form. Data Envelopment Analysis (DEA) is the most widely used technique. It is easier to implement and can be used to multiple inputs and multiple outputs. However, it has the disadvantage that is not subjected to statistical tests.

This paper focuses on the beam trawl fleet that operates in the centre-north of Portugal, and aims to estimate the technical efficiency of this in 2004 and to assess the evolution of that efficiency for the period ranging from 1995 to 2004. The results achieved with the present study will contribute to improve the management of this fishery.

2. METHODOLOGY

This section presents the SFA technique, used to measure the efficiency in the beam trawling fishery for the year 2004, and the Malmquist index, which uses the DEA technique to assess progress in productivity over the period 1995-2004.

2.1. Stochastic Frontiers

Meeusen and van den Broeck (1977) and Aigner et al. (1997) proposed the estimation of the stochastic production frontier. Initially, the production function was specified for cross-sectional data in accordance with the model:

$$Y_i = x_i\beta + (V_i - U_i),\ i=1,...,N, \tag{1}$$

where Y_i is the production (or logarithm of production) of the i-th vessel; x_i is a $(k\times1)$ vector (or transformations of the) of inputs of the i-th vessel; β is a vector of unknown parameters; V_i is a random variable which are assumed to be iid. N $(0,\sigma_V^2)$, and independent of the U_i; and, U_i is a non-negative random variable associated with the technical inefficiency in the production of the i-th vessel ($U_i \geq 0$). The random variable (V_i), can be positive or negative and accounts for measurement error and other random factors as effects of weather, strikes etc. assuming that it is independent and identically distributed (iid) with mean zero and constant variance (σ_V^2) independent of the variable U_i. The existence of the variable V_i gives the name of this stochastic frontier production function. The elimination of this variable implies a deterministic frontier model where there would not be measurement errors and all deviations of the frontier are due to technical inefficiency, which has been criticized as cited by Coelli et al. (1998). The variable U_i reflects the effects of inefficiency technique, so the question is to define which type of distribution is more appropriate. Initially, it was assumed that U_i followed a half-normal distribution with mean zero and variance σ_U^2, but immediately appeared criticisms, so that the option for the truncated-normal distribution with mean μ and variance σ_U^2. The estimation of the truncated-normal stochastic frontier involves the estimation of the parameter, μ, together with the other parameters of the model, then we can test the hypothesis H_0: $\mu=0$ (half-normal distribution) against H_1: $\mu\neq0$ (truncated-normal distribution).The truncated-normal distribution is a generalization of the half-normal distribution. If we cannot reject H_0 the half-normal distribution can be used. This hypothesis can be tested using the Likelihood Ratio (LR) test or the Wald test.

2.1.1. Functional form of the production function

The most commonly used functional form is the Cobb-Douglas function due to its simplicity, because it is enough to apply logs to have a linear function that is easy to estimate. However this function has some restrictive properties like having constant input elasticities and unitary elasticity of substitution. The alternative functional form is the most commonly used translog function, which does not impose restrictions upon returns to scale or substitution possibilities, but has the drawback of being susceptible to multi-collinearity and degrees of freedom problems (Coelli *et al.*, 1998). In the selection of the functional form of the production function both models can be estimated and test the null hypothesis that the Cobb-Douglas is an adequate representation of the data against the alternative hypothesis of translog. The stochastic production frontier can be represented in the translog form by (Coelli *et al.*, 1998):

$$\ln Y_i = \beta_0 + \sum_{j=1}^{m} \beta_j \ln x_{ji} + \sum_{j\leq}^{m} \sum_{k=1}^{m} \beta_{jk} \ln x_{ji} \ln x_{ki} + V_i - U_i \qquad (2)$$

where there are m inputs (x's) and one output (Y) for each of the i-th vessel and the corresponding stochastic production frontier in the Cobb-Douglas form by:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{m} \beta_j \ln x_{ji} + V_i - U_i \qquad (3)$$

and, we can test the null hypothesis: H_0: $\beta_{jk} = 0$ (Cobb-Doulgas is adequate) vs. H_1: Translog is adequate, using the Likelihood-Ratio statistic (LR_{CD} = -2 {ln[L(H_0)] – ln[L(H_1)]}; where L(H_0) is the value of the likelihood function under H_0 (Cobb-Douglas) and L(H_1) is the value of the likelihood function under H_1 (translog). If $LR_{CD}>\chi^2_n \Rightarrow H_0$ is rejected and therefore the translog model is applied. The n index in χ^2_n corresponds to degrees of freedom, which are the excess of parameters estimated in the Translog.

2.1.2. Maximum Likelihood Estimation

Using the parameterization of Battese and Corra (1977) and reminding that U_i is assumed to be iid truncated at zero $|N(\mu,\sigma_U^2)|$ and Vi is assumed to be iid $N(0,\sigma_V^2)$, the likelihood function in terms of two parameters of variance can be expressed as:

$$\sigma^2=\sigma_V^2+\sigma_U^2 \quad (4)$$

$$\gamma=\sigma_U^2/(\sigma_V^2+\sigma_U^2) \quad (5)$$

The ML estimators of β, σ^2 and γ will be determined by the calculation of the maximum of likelihood function presented in Battese and Coelli (1992). According to Coelli (1996a), the software Frontier 4.1 obtains the estimates of the former parameters through three steps and gives estimates of the technical efficiency of each i-th vessel, as well as technical efficiency mean of all vessels (such as arithmetic mean of individual estimates). Given the stochastic frontier model, we can test H_0: $\sigma_U^2=0$ (absence of technical inefficiency effects in the model) against H_1: $\sigma_U^2>0$. As Coelli *et al.* (1998) stated "If this variance is zero, then all the U_i's are zero, implying that all vessels are fully efficient". However the parameterization of Battese and Corra (1977), was followed by applying the software Frontier 4.1 to test the equivalent hypothesis H_0: $\gamma=0$ (absence of technical inefficiency effects in the model) against H_1: $\gamma>0$ using Likelihood Ratio (LR) test:

$$LR_\gamma = -2 \{\ln[L(H_0)] – \ln[L(H_1)]\} \quad (6)$$

where $L(H_0)$ is the value of the likelihood function under H_0 (estimated in the model without U_i) and $L(H_1)$ is the value of the likelihood function under H_1.

The LR_γ statistic has asymptotic distribution, which is a mixture of chi-square distributions, whose critical values were taken from Kodde and Palm (1986). If LR_γ > critical mixed $\chi^2_m \Rightarrow$ rejection of H_0 for a test of size α. The “m” index refers to degrees of freedom corresponding to the number of restrictions. If the null hypothesis is not rejected then the term of inefficiency should be removed from the model and the model and can be estimated by the OLS method. As $0\leq\gamma\leq1$, so $\gamma=1$ is the same as $\sigma_V^2=0$, therefore the stochastic frontier model is not different from the deterministic frontier model, that is, there is no random errors in the production function, all deviations are due to inefficiency.

2.1.3. Technical Efficiency Estimation

The measurement of vessel technical efficiency is based upon deviations of observed from efficient production frontier. It is estimated by the ratio of observed product in the i-th vessel (Y_i*) to potential output (Y_i), defined by the frontier. When the dependent variable is in logs, the technical efficiency of the i-th vessel is given by:

$$TE_i = Y_i^* / Y_i = \exp(-U_i) \qquad (7)$$

When the dependent variable is in levels, the technical efficiency of the i-th vessel is given by:

$$TE_i = Y_i^* / Y_i = (x_i\beta - U_i) / x_i\beta \qquad (8)$$

The technical efficiency estimation using stochastic frontiers is an output-orientated measure, which takes a value between 0 and 1. The technical efficiency of the i-th vessel (TE_i) indicates the magnitude of the output of the i-th vessel in relation to output that could be produced by a fully efficient vessel using the same inputs.

2.2. Malmquist Index

In the present study the Total Factors Productivity (TFP) is measured using the Malmquist Index. This index is defined through distance functions and uses the Data Envelopment Analysis Method (DEA) to calculate distance measures. These functions allow describing a multi-input or multi-output production technology without the need to specify an objective function. Although distance functions can be defined for both inputs and outputs variables, in this study only output distance functions were considered. According to Coelli and Rao (2005) the production technology may be defined using the output set, P(x), which represents the set of all output vectors, y, which can be produced using the input vector, x. That is:

$$P(x) = \{ y: x \text{ can produce } y\} \qquad (9)$$

Assuming that the technology satisfies the axioms set listed in Coelli *et al* (1998), the output distance function is defined on the output set, P(x), as:

$$d(x,y)=\min\{\delta:(y/\delta)\in P(x)\} \qquad (10)$$

The distance function d(x,y), take values less or equal to one if the output vector, y, is a element of the feasible production set, P(x). The distance function will have a unitary value, if y is located on the boundary of the feasible production set and in this case is considered technical efficient.

The Malmquist Index measures the Total Factor Productivity Change (TFPCH) between two periods, by calculating the ratio of the distance of each data point relative to a common technology. According to Färe *et al.* (1994) and Kirikal (2004), the Malmquist index, output oriented, between the period t and (t+1) can be given by two components formula:

$$m_{t,t+1}(y^t, y^{t+1}, x^t, x^{t+1}) = \frac{d^{t+1}(y^{t+1}, x^{t+1})}{d^t(y^t, x^t)} \left[\frac{d^t(y^t, x^t)}{d^{t+1}(y^t, x^t)} \times \frac{d^t(y^{t+1}, x^{t+1})}{d^{t+1}(y^{t+1}, x^{t+1})} \right]^{1/2} \quad (11)$$

where *d* represents the distance function and the value of m is the Malmquist index of total factors productivity change (TFPCH).

A value of m greater than one denotes productivity growth between the period *t* and the period (*t*+1), while a value of *m* less than one indicate productivity decline, and *m* equal to one indicates no productivity change. In the previous equation the term outside the brackets is a ratio of two distance functions, which measures the change in the technical efficiency between two periods (EFFCH). That is, the efficiency change is equivalent to the ratio of the technical efficiency technique in the period (*t*+1) and the technical efficiency in period *t*. If this term (EFFCH) is greater than one it means that the agent is moving closer to the production frontier, is less than one if diverging from the production frontier and is equal to one if the technical efficiency unchanging.

The square root term of the previous equation is a measure of the technical change in the production technology (TECHCH). It is the geometric mean of the shift in technology between two periods. If the term (TECHCH) is greater than one means that the technological best practice is improving, is less than one if the technological best practice is deteriorating and is equal to one if the technological best practice is unchanged.

2.3. Data analysis

In our study we have cross-sectional data for 2004 and a panel data ranging from 1995 to 2004. For the first study it was used data from 89 vessels, whereas in the second study only data from 34 vessels were analysed. Since during the period in analysis some vessel left the fishery while other become active, it was decided to consider within the period 1995-2004, a sub-period (2000-2004), which allowed to study the evolution of 69 vessels.

In the estimation of the technical efficiency for 2004, the SFA technique was used, because it allows the testing of hypotheses at the selected production function. However, the data from some years of the period from 1995 to 2003 have some problems using the SFA technique, for this reason we use the Malmquist Index (based in DEA techniques, which are more flexible), to asses the evolution of the efficiency.

3. RESULTS

3.1. Technical Efficiency

3.1.1. Model selection

The first step of the study was to define which model (the Cobb-Douglas production function or the translog production function) fits better the data for the beam trawl fleet in 2004. The data used comprised one output (landings in weight and in value) and four inputs variables, three of them are fixed and were related with the characteristics of vessels (overall length, gross tonnage and engine power) and one was variable (days of fishing). We need to estimate a stochastic production frontier with the goal of estimate the technical efficiency of each vessel and of the fishing gear, but the methodology described in section 2.1 accepts only a single output, so we consider as output in the model the landings in kgs (Q). As inputs we have the length (CP), the tonnage (TN), the power engine (PT) and the days of fishing (DM). Thus, the stochastic production frontier may take two forms. According to the Cobb-Douglas function we have:

$$\ln(Q_i) = \beta_0 + \beta_1 \ln(CP_i) + \beta_2 \ln(TN_i) + \beta_3 \ln(PT_i) + \beta_4 \ln(DM_i) + (V_i - U_i) \qquad (13)$$

where Ln is the natural logarithm of the variables and the “i” index refers to the i-th vessel. β’s are the parameters to be estimated. V_i and U_i are respectively the stochastic error and the non-negative random term to estimate the technical inefficiency, as explained in section 2.1. According to the translog function we have:

$$\ln(Q_i) = \beta_0 + \beta_1\ln(CP_i) + \beta_2\ln(TN_i) + \beta_3\ln(PT_i) + \beta_4\ln(DM_i) +$$
$$+ \beta_{11}\ln^2(CP_i) + \beta_{22}\ln^2(TN_i) + \beta_{33}\ln^2(PT_i) + \beta_{44}\ln^2(DM_i) +$$
$$+ \beta_{12}\ln(CP_i)\ln(TN_i) + \beta_{13}\ln(CP_i)\ln(PT_i) + \beta_{14}\ln(CP_i)\ln(DM_i) +$$
$$+ \beta_{23}\ln(TN_i)\ln(PT_i) + \beta_{24}\ln(TN_i)\ln(DM_i) + \beta_{34}\ln(PT_i)\ln(DM_i) + (V_i - U_i) \quad (14)$$

Where we add to the Cobb-Douglas the squared independent variables and the cross products of independent variables. It was estimates the stochastic frontier for these two functions in order to select one of them, according to the test specified in section 2.1. Moreover, it was also tested if the random term associated with inefficiency (U_i) has zero mean (μ=0), following a half-normal distribution. Otherwise follows a truncated normal distribution. This involves estimating six models to select one. With this purpose, the software Frontier 4.1 was used on annual data (cross-section) per vessel. The frontier function estimates were used to test three different assumptions about the disturbances terms:

- Model 1 assumes all parameters are estimated;
- Model 2 assumes that $\mu = 0$;
- Model 3 assumes that $\gamma = \mu = 0$.

Model 1 is the stochastic frontier production where U_i's are non-negative truncations of the $N(\mu,\sigma_U^2)$. Model 2 is the special case of Model 1 in which the U_i's have half-normal distribution. Model 3 is the traditional average response function in which vessels are assumed to be fully technically efficient (i.e., U_i are absent from the model).

Table 1. Tests of hypothesis to select the stochastic frontier model for the beam trawl fleet in 2004

Model	**H0**	CD function	TL function	Decision
3 vrs 1	$\gamma = \mu = 0$	$LR_\gamma(2) = 6{,}28^{**}$	$LR_\gamma(2) = 189{,}28^{***}$	Reject H0
2 vrs 1	$\mu = 0$	$LR_\mu(1) = 5{,}76^{**}$	$LR_\mu(1) = 57{,}89^{***}$	Reject H0
CD_1 vrs TL_1	$\beta_{jk} = 0$	_	$LR_{CD}(10) = 10{,}98$	Accept H0

** P<0.1; ** P<0.05; *** P<0.01.*

LR(df): Likelihood-ratio statistic, between brackets are the degrees of freedom; CD: Cobb-Douglas; TL: Translog; CD_1 vrs TL_1 : Cobb-Douglas function versus Translog function that involves all the parameters being estimated (truncated-normal distribution).

We estimated this three models on two functional forms: Cobb-Douglas (CD) function and Translog (TL) function. After the estimation, we applied tests of hypotheses involving the parameters of the distributions, using the generalized likelihood-ratio statistic (Table1). It is evident that the model 3 is not an adequate representation of the data (the null hypothesis H0: $\gamma = \mu = 0$ is rejected). The hypothesis that the half-normal distribution is an adequate representation for the distribution of the vessels effects (H0: $\mu = 0$) is also rejected.

The selection of the best model was made in accordance with the methodology described above (LR_{CD}), estimating a Cobb-Douglas versus a Translog function and applying the Likelihood Ratio test. According to LR_{CD} the null hypothesis (H0: $\beta_{jk}=0$) that the Cobb-Douglas function in an adequate representation of the data cannot be rejected, therefore the Cobb-Douglas functional form is appropriate. Thus, it was selected a truncated-normal Cobb-Douglas model

3.1.2. Technical efficiency estimation in 2004

The result of the stochastic frontier estimation in accordance with the functional forms selected in section 3.1.1, the Cobb-Douglas functional form, is presented in table 2. The parameter γ is equal to 1, which means that the model of stochastic frontier may not be significantly different from the deterministic frontier. In this case all the deviations will be due to inefficiency.

Table 2. Results of the stochastic frontier estimation (Cobb-Douglas functional form) for the beam trawl fleet in 2004. Dependent Variable: landings in kg.

Variables	Coeficients	Standard-Deviation	T - ratio	
Constant	1.85879	0.81486	2.28111	**
ln CP	0.56852	0.54086	1.05115	
ln TN	0.39185	0.24863	1.57603	
ln PT	0.39968	0.12441	3.21259	***
ln DM	0.86547	0.02783	31.10067	***
σ^2	0.72427	0.11088	6.53227	
γ	1.00000	0.00013	7731.37540	***
μ	1.32638	0.04981	26.62684	***

** P<0.1; ** P<0.05; *** P<0.01.*

It was observed that the output (landings in kgs) depends positively and significantly of the engine power (PT) and the number of days at sea (DM) at 1 % level of significance. This means that when engine power and the number of days at sea increase 1%, the landings in kgs will increase about 0.4 % and 0.9 %, respectively. The elasticities of the overall length (CP) and of the gross tonnage (TN) has also the positive sign, but they are insignificant at 5% level. The total elasticity of this frontier function is 2.23, indicating increasing returns to scale.

The technical efficiency estimation from these stochastic frontier models is presented in Table I (in Annex) and in Figure 1. In the beam trawling fishery the efficiency ranged from a minimum of 0.03 and a maximum of 1, with a mean of 0.31 and a median of 0.29 (Table 3) and 40 vessels out of 89, showed above-average technical efficiency. There were 3 vessels that presented a maximum efficiency (Table I in Annex and Fig. 1). The results also indicated that 22 boats had an efficiency below the first quartile (0.12) while 23 had an efficiency above the third quartile (0.41) (Table 3).

Figure 1. Technical Efficiency estimated for each vessel of the Portuguese beam trawl fleet that operates on the Centre-North of the western coast.

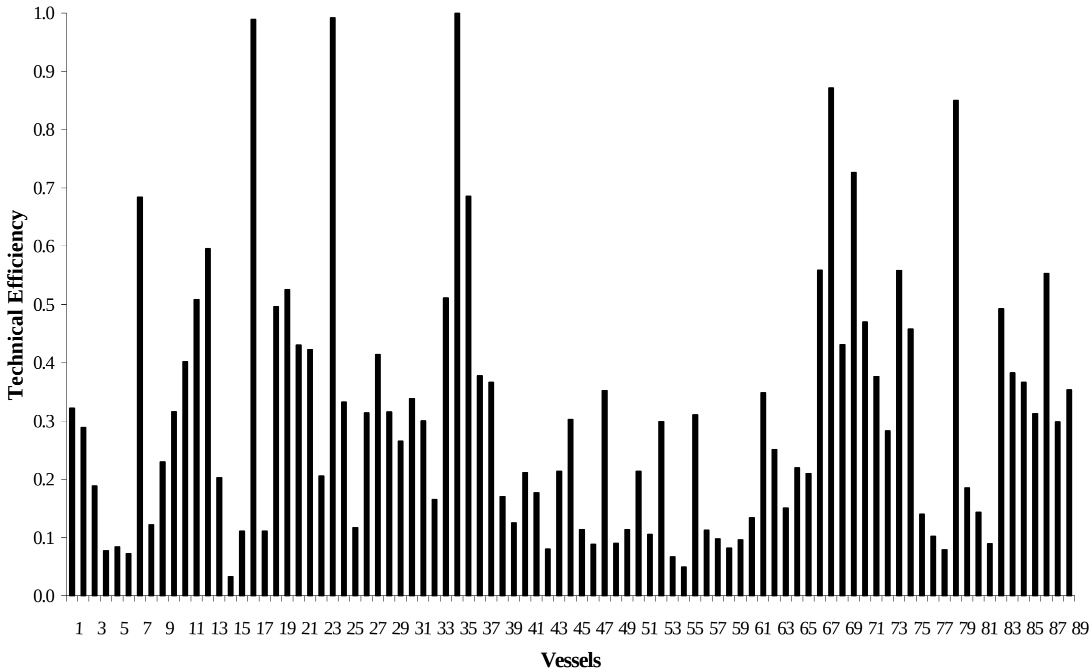


Table 3. Descriptive statistics of the technical efficiency estimated for the beam trawl fleet in 2004.

Statistics	
Mean	0.31
Median	0.29
Q1	0.12
Q3	0.41
Standard Deviation	0.23
Variation Coef.	72.42
Min	0.03
Max	1.00

3.2. Technical Efficiency Changes

The analysis of the Technical Efficiency Changes of the beam trawl fleet aimed to verify the existence of technical efficiency gains overtime. Taking into consideration the data available, two periods of analysis were considered (1995-2004 and 2000-2004). We consider as output in the model the landings in kgs and as inputs we have the length, the tonnage, the power engine and the days of fishing. To assess the evolution of the efficiency, we use the DEAP (Coelli, 1996b), which applies the Malmquist Index to estimate the Technical Efficiency Changes (EFFCH), Technical Change of Production Technology (TECHCH) and Total Factor Productivity Change (TFPCH). Table 4, presents the annual averages of the Malmquist Index for the period 1995-2004.

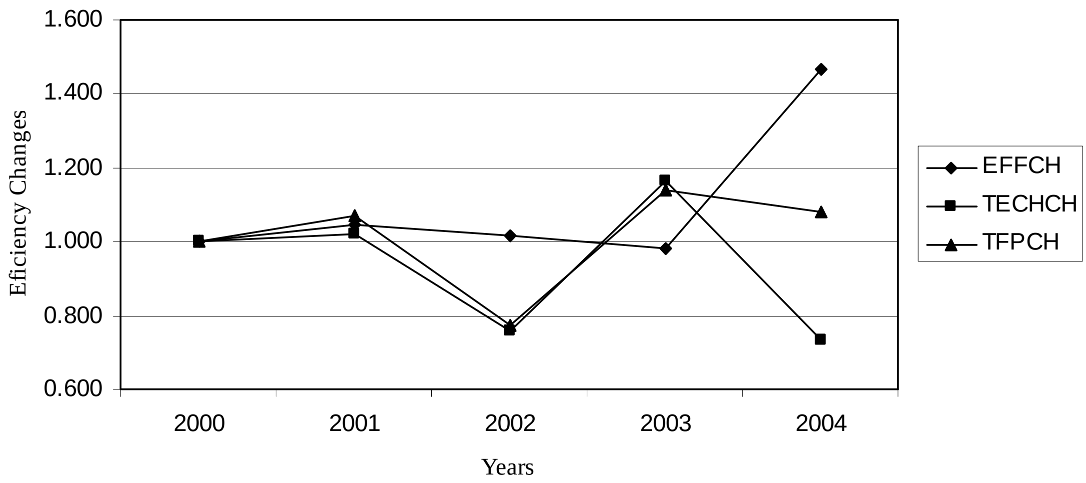
Table 4. Annual averages of the Malmquist Index for the beam trawl fleet between 1995-2004. EFFCH - Technical Efficiency Changes; TECHCH - Technical Change of Production Technology; TFPCH - Total Factor Productivity Change.

Year	*EFFCH*	*TECHCH*	*TFPCH*
1995	1.000	1.000	1.000
1996	0.786	1.114	0.875
1997	1.596	0.555	0.886
1998	0.660	1.652	1.091
1999	0.732	1.511	1.106
2000	1.418	0.599	0.849
2001	1.217	0.921	1.121
2002	0.954	0.792	0.755
2003	0.997	1.177	1.174
2004	1.462	0.782	1.144
Mean	1.042	0.948	0.989

In respect to Technical Efficiency Changes (EFFCH) and Technical Change of Production Technological (TECHCH) it was observed there are great oscillations of these indexes throughout the period analysed. These indexes showed opposed behaviours, since when one increases the other decreases and *vice versa*. This behaviour can be justified for the raised variability of the fleet, in consequence of oceanographic conditions. In average terms, Technical Efficiency grew slightly (4.2%) throughout the period in analysis, whereas Technological Changes decreased 5.2%. This result suggests technological losses between 1995 and 2004. The conjugated effect of these two measures originated, in average terms, a small decrease of the Total Factors Productivity, that lowered 1.1%.

Figure 2 presents the evolution of EFFCH, TECHCH and TFPCH for the period ranging from 2000 to 2004. It keeps a higher stability throughout the period because it is the result of the two previous indexes product. It can be observed that the three indices varied in a similar way of the previous analysis. In average terms, the beam trawling fleet was moving closer to the production frontier, the technological change decreased while Total Factors Productivity increased. The following figure represents the evolution of the Indexes in period 2000-2004.

Figure 2. Annual averages of the Malmquist Index for the beam trawl fleet between 2000-2004. EFFCH - Technical Efficiency Changes; TECHCH - Technical Change of Production Technology; TFPCH - Total Factor Productivity Change.



It can be concluded that the fleet did not show great changes in efficiency, with the Total Factor Productivity increasing slightly, due to positive change of technical efficiency, that compensated the negative change in technological production.

4. CONCLUSIONS

The efficiency of the beam trawl fleet in 2004 was estimated, with parametric methods. To obtain the frontier form of production possibilities, we used the Stochastic Frontier Analysis (SFA) Technique. The evolution of efficiency was based in non-parametric methods namely the Malmquist Index, which is based on Data Envelopment Analysis (DEA) techniques. The results indicated that the technical efficiency of the Portuguese beam trawl fleet that operates in the centre-north of Portugal was relatively low. It was observed that the output depends positively and significantly of the engine power and the number of days at sea. In average terms, the efficiency was only about 30%, and only 4% of the boats attained it. The results showed a slightly decrease in the total factors productivity. This is a symptom of some inefficiency of the artisanal fishing sector, which has a greater role in social terms than in the economic ones. Technical Efficiency grew slightly (4.2%) between 1995 and 2004, whereas Technological Change decreased (5.2%), indicating that the beam trawl fleet had technological losses during the studied period. The conjugated effect of these two measures lead to a small decrease of the Total Factors Productivity. The 4 years analysis showed a similar trend in the three efficiency indices, when compared with the results obtained when the analysis was undertaken for 9 years.

This work has some inherent limitations due to the type of data used. Indeed, if a larger number of inputs would have been used, a higher precision in the efficiency estimation probably would have been achieved. The application of this methodology to other fishing gears in Portugal would give rise to interesting results and would allow the adoption of national/regional management strategies most centred in the economic subject. Besides this, the results obtained in this study may be very useful to obtain a better management of the beam trawl fishery.

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ANNEX

Table I. Technical Efficiency (TE) of the beam trawl fleet in 2004

Vessels	TE	Vessels	TE
1	0.32	46	0.11
2	0.29	47	0.09
3	0.19	48	0.35
4	0.08	49	0.09
5	0.08	50	0.11
6	0.07	51	0.21
7	0.68	52	0.11
8	0.12	53	0.30
9	0.23	54	0.07
10	0.32	55	0.05
11	0.40	56	0.31
12	0.51	57	0.11
13	0.60	58	0.10
14	0.20	59	0.08
15	0.03	60	0.10
16	0.11	61	0.13
17	0.99	62	0.35
18	0.11	63	0.25
19	0.50	64	0.15
20	0.52	65	0.22
21	0.43	66	0.21
22	0.42	67	0.56
23	0.21	68	0.87
24	0.99	69	0.43
25	0.33	70	0.73
26	0.12	71	0.47
27	0.31	72	0.38
28	0.41	73	0.28
29	0.31	74	0.56
30	0.26	75	0.46
31	0.34	76	0.14
32	0.30	77	0.10
33	0.16	78	0.08
34	0.51	79	0.85
35	1.00	80	0.19
36	0.69	81	0.14
37	0.38	82	0.09
38	0.37	83	0.49
39	0.17	84	0.38
40	0.12	85	0.37
41	0.21	86	0.31
42	0.18	87	0.55
43	0.08	88	0.30
44	0.21	89	0.35
45	0.30	Mean =	**0.31**