Fishing Effort Validation and Substitution Possibilities among Components: The Case Study of the VIII Division European Anchovy Fishery ·:

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Abstract

Command and control regulation programs, particularly input constraints, typically fail to achieve stated objectives, because fishermen may substitute unregulated for regulated inputs. It is, thus, essential to have an understanding of the internal structure of production technology. A primal formulation is used to estimate a translog production function at the vessels level that includes fishing effort and fisherman's skill. The flexibility of the selected functional permits the analysis of the substitution possibilities among inputs by estimating the elasticity of substitution with no prior constraints. Particular attention is paid to the empirical validation of fishing effort as an aggregate input, which implies either, the acceptation of the joint hypothesis that inputs making up effort are weakly separable from the inputs out of the subgroup or considering that effort is an intermediate input produced by a non-separable two stage technology. Cross sectional data from the Spanish purse seine fleet operating in the VIII Division European anchovy fishery provide evidence of limited input substitution possibilities among the inputs making up the empirically validated fishing effort translog micro-production function.

Key Words: Elasticity of Substitution, Fishing Effort; Fisherman's Skill, Translog Production Function; Separability; VIII Division European Anchovy.

JEL category: Q22; Q28.

1. INTRODUCTION

The input quantity controls frequently used to regulate overexploited resources in fisheries management programs limit the availability inputs. Firms might then face the shortages of inputs with the reallocation of non-limited inputs, and even might subvert any imposed restrictions. Consequently, one of the crucial problems in the design of rationing programs is anticipating the firm’s behaviour in response to changes in rations and market conditions under rationing (Squires, 1994).

Fishing effort is an aggregate input of different production factors. Traditional regulation programs based on directly limiting effort have been shown to require the restriction of one or more of its components in order to avoid inefficient expansions of unregulated inputs (Wilen, 1979; Campbell, 1991; Dupont, 1991; Squires, 1987(a), 1987(b). Consequently, the empirical knowledge of its components and the evaluation of the substitution possibilities among them is fundamental when trying to guarantee the contention of fishing effort in a specific fishery.

The VIII Division anchovy fishery shows evidence of failure of the TAC (Total Allowable Catches)/licensing regulation system (del Valle et al., 2001). Although recently the European Commission has approved restrictions on the TAC, fishing calendar and fishing zones, the empirical evidence derived from such restrictions suggests that we should not be very optimistic. Even in the case that the reduction of the TAC does not increase the race to fish, input limitation may induce inefficient input expansions. In this framework, the estimation of the elasticity of substitution among inputs could be valuable to determine whether input restriction is an efficient form of regulation for the fishery.

The purpose of this paper is to undertake an empirical analysis of the production technology for the VIII Division European anchovy fishery. In particular, the potential for effort to be a composite input, as well as the relationship between inputs making it up will be investigated. We initially specify a flexible functional form (i.e., the translog) to estimate the underlying primal technology at the vessel level including the fishing effort and a proxy for the fishermen's skill. Next the conditions consistent with strong, linear, and non-linear separability are imposed in order to test for the existence of a consistent composite input defined as fishing effort.

Although rejection of separability does not rule out the possibility that effort is an intermediate input produced by a non-separable two stage technology (Pollak and Wales, 1987(a), 1992(b)), the acceptation of weak separability guarantees the existence of a consistent aggregator function for the components of effort (Berndt and Chirstensen (B&C) 1973(a); (B&C), 1973(b); Solow, 1955; Squires 1987(a), Squires 1987(b); Squires, 1992). Once accepted, weak separability restrictions will be introduced in the translog model. The robustness of the restricted least square estimators will then be confirmed by demonstrating that the elimination of all the highly leveraged observations and outliers that contributes significantly to the values of the coefficient estimates and/or the model predictions do not substantially change the estimated coefficients and the partial elasticity of production. Finally the Allen and Morishima elasticities of substitution will be evaluated and compared. The paper ends with the main conclusions and policy implications derived from the production analysis.

2. THE FISHERY BACKGROUND

Anchovy is a short life span and small in size schooling species. The findings of biological research into the anchovy stock suggest that the population fluctuates according to variations in recruitment, which in turn seems to be closely related to environmental conditions like the phenomenon of upwelling in the Gulf of Biscay. Management experiences of pelagic species in Northern Europe, however, seems to indicate that pelagic stocks may require a critical breeding biomass, below which the likelihood of strong recruitment would be seriously jeopardised. It is in the light of this information that experts argue that the stock stands at appreciably lower levels than in previous decades. In addition to this, a decrease has been observed in the average age of the anchovy caught, which would seem to confirm the increase in fishing mortality rate.

Two different fleets, the Spanish purse seine and the French pelagic trawling fleet, exploit the stock. The purse seine fleet has been undergoing a continual reduction in size to the point that the number of vessels has dropped from 600 in 1966 to a current 250. The French pelagic fleet, on the other hand, has enjoyed spectacular growth, bringing about, with its approximately 100 vessels, and in spite of the decline of the purse seine fleet, a considerable increase in the fishing pressure on the anchovy stock (Graph 1).

Until the mid eighties about 90% of anchovy catches were taken by the Spanish purse seine fleet, 70% of this amount was caught by the Basque fleet. Nevertheless, with Spain's entry into the European Union, France's share in the catch increased considerably, to the point that now a days the volume of catches of the two states are similar (Graph 2).

The total anchovy catches in the Bay of Biscay vary considerably from one year to another. After reaching a historic high of over 80,000 tons in the mid-sixties, anchovy catches began a drastic decline lasting until the mid-seventies. 1975 heralded a period of relative growth probably due to technological advances such as radar and sonar. From 1978 onwards, however, there was another steep drop in catches, culminating in the historic lows of 1982 and 1986 when they dropped to 5,000 and 8,000 tonnes respectively. The early nineties saw noticeable recuperation, with catches of over 30,000 tons. The last fishing seasons, nevertheless, have been poor, especially for the purse seine fleet.

Since the mid-eighties, the European Union has placed a TAC of 33,000 tons and a licensing system. 90% of the 33,000 TAC goes to Spain by virtue of the principle of relative stability endorsed in the European Fisheries Policy. Since 1992, 9,000 tons of the unfished Spanish quota has been transferred to France following bilateral agreements signed by the two countries[2]. Furthermore, France has received a transfer of 6,000 tons of anchovy from Portugal's IX Division anchovy-quota, which is being fished from the VIII division stock.

Despite the restrictions, there are important shortcomings in anchovy fishery regulation (del Valle et al., 2001). The licensing system has in practice placed no barrier at all to the entry of new vessels; the TAC, which shows clear signs of being too high for the anchovy population, is established with scant scientific back-up and there are also apparent problems in monitoring. Added to this, the adverse environmental conditions during 1999 and the foreseen reduction in the spawning biomass expected to bring it below secure levels (ICES, 1999) has induced the European Commission to approve restrictions in the TAC and fishing calendar.

3.MODEL ESTIMATION AND HYPOTHESIS TESTING

3. 1. Inputs [i.e. fishing effort, skipper skill] and data

The volume of a vessel's catch depends on the quantity of fishing effort. Our testable hypothesis is that fishing effort is a multidimensional and flexible production factor, or in other words, an aggregator micro-production of different fixed and variable inputs. It is the combination of a certain intensity or magnitude respecting the activity of the fishermen (number of boat days, number of trips, etc), the physical attributes of fishing vessels (tonnage, horsepower, length, etc), the gear or equipment that the fishermen uses to extract the catch (number of hooks set, number of shots made, etc), etc.

Nevertheless, the factors making up effort can be sometimes even less significant than those related to the skill in making managerial decisions such as how, where, or when to stop fishing. The notion that some fishing captains are better managers than other captains, and in turn, consistently have higher production and earnings has long been recognised by fishery researchers (Cominiti and Huang,1967; Rothschild, 1972; Acheson, 1975; Bjørndal, 1989; Thorlindsson; 1987; del Valle et al., 1997 Kirkley et al., 1998; Squires and Kirkley, 1999) and by the own sector.

Skipper skill is related to information gathering and utilisation, including finding and catching fish, managing and supervising crew, responding to changing tides and weather, seasonal variations in resource abundance, and numerous other factors[3]. The question arises when analysing the fishery production process of how to specify the above-mentioned characteristics consistently in order to incorporate them into a production function suitable for econometric estimation. Different approaches have been used in empirical studies to capture the influence of the skill in the production function. A recent summary is provided in Balestra (1996) and in Squires and Kirkley (1999).

Some authors (Cominiti and Huang, 1967; Campbell, 1991) used a subjective evaluation of the managerial skills of the boat captains supplied by a person who was thoroughly familiar with the boats and captains implied in the fishery they were analysing. Another approach has followed a direct measurement of fishing skill. Holt (1962) utilised a measure based on he proportion of successful pursuits adjusted for vessels characteristics and days of effort, while in Mefford (1988) management is measured as a performance ranking of each plant compared to all other plants on output goal attainment, quality level of the output, and cost (factory budget over or under fulfilment). More recently, Kirkley et al. (1998) equated technical efficiency (TE) to skipper skill and then examine the relationship between TE and two possible indicators of skill –years experience in fishery and education level - of captains[4].

Several limitations can arise when using any of the above-mentioned methods to introduce the management into the production function. While using indexes of management derived from performance rankings can be regarded as an ad hoc procedure as long as no criterion for evaluating its performance is available, identifying TE with skill there is a danger that in what we refer to as management, we also include the effects of factors that do not depend on it. Besides, when trying to link skill with different characteristics of the skippers (experience, age, education level) sometimes no significant statistical relationship has been found among them and catch rates (Acheson, 1975; Palsson and Durremberger, 1982; Squires et al.,1998). In the case of the direct approach, as with all proxy variables used to capture something with no observable counterpart, measurement error and bias can follow.

The concepts of skipper skill and fishing effort above mentioned will be applied to the Spanish purse seine fleet operating in the VIII Division European anchovy. For the purposes of the study, annual cross sectional data is available for 183 out of the 250 Spanish purse seine operating in the anchovy fishery during the year 1995. Data set includes catches (Y), boat days (BD), gross registered tonnage (GRT), engine horsepower (HP), length (L), hull's material type (MT), the shipbuilding year (SY) and the number of unloading (NU) with the respective quantity caught whenever the boat arrives to the harbour. A summary of the cross-sectional data is given in Table I. Data on harvest quantities and variable inputs have been made available by AZTI. The Department of Agriculture and Fishery of the Basque Government has been publishing data on vessel characteristics since 1987.

The lack of the data necessary to evaluating any of the characteristics of skill, and the impossibility to construct a subjective ranking of the captains[5], obliged us to adopt the direct measurement approach (Holt, 1962; Mefford, 1986). The fishermen operating in the anchovy fishery return every day from the fishing grounds, even if they do not get catches. Consequently, the ratio number of significant unloadings[6] to number of total unloadings could be a good representation of the variable skill (SK). Proof of this is that the resulting ranking of the vessels coincides in most cases with the reputation of the vessels among the different fishermen asked in the main harbors of the east Cantabrian Sea. As with all proxy variables used to capture something with no observable counterpart, measurement error and bias can follow, although the asymptotic bias expected from inclusion is generally smaller than for exclusion.

As well as the mentioned proxy for the fisherman skill, the empirical analysis considers tonnage[7], horsepower, boat days, the year built and the material type[8]. The GRT represents a measure of the potential cargo capacity, which sets an upper limit on catch per trip. Furthermore, HP influences the speed of boats, while BD is a widely accepted variable production input in fisheries economics. Two variables that may influence production per boat have been excluded from the analysis: stock size[9] and aggregate number of boats in the fishery. The reason for this omission is due to the cross sectional nature of the data, which implies that stock size and fleet participation are assumed to be constant and equal for all boats. Although technical fish finding equipment also affects production, all purse seines were equipped with sonar and echo-sounder.

The hypothesis that effort is an aggregate index of boat days and vessel characteristics (GRT, HP) will be tested. If this can be proved, it will show that effort is a micro production function within a macro function, which as well as effort also includes skill. As the effort's theoretical consistency requires technology to be weakly separable[10], different separability tests will be carried out once the parameters of the translog production function have been estimated. The acceptation that factors made up of effort are separable from skill implies the empirical validation of fishing effort as a consistent aggregate input.

3. 2. The translog model

The translog production function (1) (B&C, 1973a) does not impose prior constraints on the sign and magnitude of the elasticities of substitution between production inputs and permits testing for structural hypotheses like separability[11]. Since it does not satisfy monotonicity and quasi-concavity globally, those regularity conditions will need checking in the estimated function prior to accepting it as a regular production function.

$$LnY = Ln\alpha_0 + \sum_{i=1}^{n} \alpha_i Lnx_i + 1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} Lnx_i Lnx_j \qquad (1)$$

Where Y is the output, α_0 the efficiency parameter, x_j is input j and α_i and β_{ij} are unknown parameters. $\beta_{ij} = \beta_{ji}$ $i \neq j$ is assumed throughout to maintain consistency with Young's theorem of integrable functions.

3.2.1. The separability conditions in the translog

The factors (ij) are separable from k if and only if $f_i\beta_{jk} - f_j\beta_{ik} = 0$[12] ((B&C) (1973(a), 1973(b)). Hence, if separability holds and if $\beta_{jk} = 0$, then $\beta_{ik} = 0$. These B&C linear separability conditions require certain equality restrictions on the Allen-Uzawa elasticity of substitution (AES) [13] concretely $AES_{ik} = AES_{jk} = 1$, and a particular functional structure of a Cobb Douglas macrofunction with translog sub-aggregates (Blackorby et al., 1977; Denny and Fuss, 1977). If however $\beta_{jk} \neq 0$ and $\beta_{ik} \neq 0$, then by substituting f_i in the previous formula a set of non-linear separability conditions are obtained ($\alpha_i/\alpha_j=\beta_{ik}/\beta_{kj}=\beta_{im}/\beta_{jm}$, (m=1,2,3)). These B&C non-linear separability restrictions imply $AES_{ij} = 1$ and $AES_{ik} = AES_{jk} \neq 1$, as well as a particular functional structure of translog macrofunctions with Cobb Douglas sub-aggregates (Blackorby et al., 1977; Denny and Fuss, 1977).

The translog is separable-inflexible. That is to say, it cannot provide a second-order approximation to an arbitrary weakly separable function in any neighbourhood of a given point. For example, a three-input translog is left with seven parameters after imposing separability, two fewer than needed to maintain it (Driscoll et al., 1992)[14]. However, the most likely contribution of flexible forms lies not in their approximation properties but in the fact that they place fewer restrictions prior to estimation than the more traditional forms.

3.2.2. The regularity conditions in the translog

Monotonicity of the translog requires the logarithmic marginal products (f_i) to be positive for all inputs. As $f_i = \varepsilon_i\ (Y/x_i)$ and since Y and x_i must always be positive, $f_i>0$ requires the logarithmic production elasticity for each input $(\varepsilon_i)>0$ to be necessarily positive. The isoquants of the translog function are strictly convex if the corresponding bordered hessian matrix (F) of first (f_i), second direct partial derivatives (f_{ii})[15] and second cross partial derivatives (f_{ij})[16] is negative definite.

The above mentioned conditions of positive monotonicity and quasi-concavity depend on the values of the inputs, the output and the individual coefficients of the estimated translog function. Thus, these conditions should be verified for each data point as originally proposed by (B&C). Nevertheless, experience shows that the available flexible functional forms such as the translog tend to violate the regularity conditions at many points in most data sets. In practice there is no unanimity of the minimum percentage of observations that should verify quasiconcavity and monotonicity so as to call a production function regular. Some authors (Corbo and Meller, 1979) mention wide enough regions satisfying the previously alluded properties while others tend to verify the regularity conditions in the geometric mean of the data. Nevertheless, a test of convexity cannot be interpreted as a strict test of the assumption of profit maximisation implied by quasi-concavity, because the flexible functional form may violate quasi-concavity even if the data comes from well-behaved technologies (Squires, 1987(a); Wales, 1977).

3.3. The measure of the substitution possibilities among inputs

Although substitution in a central issue in production theory, even today, there appears to be a little agreement about the way this concept is to be defined. Since in a classic work, Hicks (1932) offered the definition of the elasticity of substitution for the uncontroversial case of two-factor technologies (σ)[17], many different generalisations of σ have been developed in the literature in order to measure the substitution possibilities in the case of technologies with more than two inputs. The most standard one is the Allen-Uzawa

Elasticity of Substitution (AES). The AES is a symmetric measure for the elasticity ($AES_{ij} = AES_{ji}$ $\forall$ ij). Qualitatively, AES classifies the pairs of inputs as complements or substitutes on the basis of its sign. So if $AES_{ij} > 0$, inputs i and j are Allen-Uzawa (net) substitutes; if $AES_{ij} < 0$ they are Allen-Uzawa (net) complements.

Despite the AES has dominated the analysis of substitution possibilities among production factors in a multifactor setting, being until recently the most estimated in empirical research, it has a number of deficiencies (Blackorby and Russell, 1989; de la Grandville, 1997); Among which are its inability to provide any information about relative factor shares and the fact that AES it is not a measure of the easy of substitution, or curvature of the isoquant[18]. Nowadays, the Morishima Elasticity of Substitution (MES)[19] is broadly accepted to be a much more satisfactory generalisation of σ. MES is an asymmetric measure of the curvature of isoquants, or the easy of substitution (in general $MES_{ij} \neq MES_{ji}$), Two factors are termed MES-substitutes if $MES_{ij}>0$ (an increase in i causes the quantity of j to increase relative to the quantity of the input i) and MES-complements, if $MES_{ij}<0$ (an increase in i causes the quantity of j to decrease relative to the quantity of the input i).

There is a necessary theoretical relationship between AES and MES[20]. If two inputs are net substitutes according to the Allen-Uzawa criterion, they must be net substitutes according to the Morishima criterion, but if two inputs are net complements according to the Allen-Uzawa criterion, they can be either net complements or net substitutes according to the Morishima criterion. Furthermore, the non-symmetry of the Morishima elasticity raises the possibility of ambiguities in the Morishima taxonomy ($MES_{ij}>0$ and $MES_{ji}<0$).

4. THE EMPIRICAL RESULTS

Initially a 4 input non-restricted translog production function was estimated (i.e. Y[GRT, HP, BD, SK]). However, the regression results simultaneously including both attributes (i.e. GRT, HP) were poor, probably due to the high collinearity between them. Although overall statistics such as $\overline{R}^2$ and F-statistic were satisfactory, many point estimates and what is more important; the derived elasticities of production were not significant or only significant at a low confidence level. On the basis of these preliminary results, we decided to go on the production analysis with the results derived from the OLS estimations of two different 3 input translog production functions: Y_1[GRT, BD, SK] and Y_2 [HP, BD, SK] (Table II).

Although not all the estimated parameters are individually significant neither in Y_1[OLS] nor in Y_2[OLS], the estimated production elasticity for each input (evaluated in their respective mean values) are in both functions significant at the 1% level (Table II)[21]. The models seem to be jointly valid and the $\overline{R}^2$ are both acceptable. In order to evaluate which of the two specifications is preferable, the Cox[22] and J[23] non-nested hypothesis tests have been carried out (see Judge et al. 1985). Both suggest that the model including GRT (Y_1) is preferred to the model that includes HP (Y_2). However, in order to add more information to derive our concluding remarks and policy implications we will present the results of Y_1 and Y_2 in parallel. The different tests (Harvey, Glegser and Breusch-Pagan-Godfrey (BPG)) that have been carried out to Y_1 and Y_2 do not detect heteroskedasticity. The Bera-Jarque test statistic leads to the rejection of the null hypothesis that errors are normally distributed, and consequently, once the separability tests are executed, we are also including trimmed least squares estimators (TLS)[24].

Next, the hypothesis that effort is an aggregate input of boat days and each of the vessel characteristics (GRT or HP) will be tested. The different restrictions to test for any type of separability[25], the F and Wald Chi statistics[26], and the critical values are summarised in Table IV. Only LS1 is found to be consistent with the data[27], which confirms that the factors (GRT, BD) and (HP, BD) are separable from skill, and consequently that: (1) Y_1 & Y_2 can be reduced to $Y_1 = F_1\{[E_1(GRT, BD)], SK\}$ & $Y_2 = F_2\{[E_2(HP, BD)], SK\}$, where Y are the catches and E_1 and E_2 are two consistent aggregator functions for fishing effort (2) the underlying functional structure for the macro functions F_1 & F_2 is a Cobb Douglas with translog micro functions for effort and skill. (3) the Allen elasticity of substitution between [GRT,HP,BD] and SK, is equal to one $\{\sigma_{GRTSK} = \sigma_{HPSK} = \sigma_{BDSK} = 1\}$.

As restricted least squares (RLS) are more efficient than OLS, the accepted linear separability restrictions have been introduced in the translog model, and the functions $\{Y_1[RLS]$ and $Y_2[RLS]\}$ have been re-estimated (Table II). Almost all the estimated parameters and what is more important, the partial elasticity of each input (ε_i) are significant at the 1% level. The models seem to be jointly valid and the value of the $\overline{R}^2$ are acceptable. The different tests (Harvey, Glegser and Breusch-Pagan-Godfrey (BPG)) which have been carried out do not detect heteroskedasticity (Table V). As in the unconstrained models, the Bera-Jarque test gives evidence of non-normality of the residuals.

Consequently, in order to verify the robustness of the RLS estimators, the translog linearly separable models will be re-estimated by TLS $\{Y_1[TLS]$ and $Y_2[TLS]\}$(Table II). In order to chose a correct trimming proportion which guarantees that all the highly leveraged observations and outliers that contribute significantly to the values of the coefficient estimates and/or the model predictions are eliminated (see Table VII for a summary), the RLS regression diagnostic has been carried out. Table VI contains the errors (e), the studentized residuals (e*), the leverage (ht), the DFFITS (DF) and the DFBETAS (DB) for the observations exceeding the rule-of-thumb cut-offs for each estimated models.

The trimming proportion that guarantees the elimination of all the influential outliers and influential high leverage observation is near 0.2, which implies the consideration of the residuals associated with the 0.2 and 0.8 quantiles. In addition to all the influential outliers and high leverage observations, the procedure has picked up some others of moderate size. Therefore, those observations where the residuals are non-positive for $\theta=0.2$ and nonnegative for $\theta=0.8$ have been discarded. Subsequently, least squares have been applied to the remaining observations {Y_1[TLS] and Y_2[TLS]}. The comparison of RLS and TLS estimators allows us to conclude that the differences are not highly significant, which in turn demonstrates that RLS estimators are robust despite the non-normality of the residuals.

Prior to accepting the validity of Y_1[RLS] and Y_2[RLS] the regularity conditions must also be examined. As the translog function does not satisfy positive monotonicity and quasi-concavity globally, those requirements need to be checked for each data point (Table VIII [A]). The different inputs considered in each estimated function satisfy monotonicity at approximately 80%, 87% and 100% of the data set. The functions Y_1[RLS] and Y_2[RLS] are quasi-concave at 70% and 58% of the sample points respectively. Positive monotonicity and quasi-concavity in the geometric mean of the data have also been checked (Table VIII [B]). Each input satisfies monotonicity and the bordered hessian matrix are negative definite (its bordered principal minors are negative and positive respectively), which implies that the estimated functions are quasi-concave in the geometric mean of the data[28].

After demonstrating that despite the non-normality of the residuals the RLS are robust and that the estimated functions are regular, the estimations of the elasticity of substitution between inputs comprising the two alternative empirically validated production functions (Y_1 and Y_2) will be considered acceptable. Table IX contains the estimates of the AES and MES between GRT and BD, derived from Y_1 (i.e. AES_{GRTBD}, $MES_{GRTBD,}$ MES_{BDGRT}) and the AES and MES between HP and BD derived from Y_2 (i.e. AES_{HPBD}, $MES_{HPBD,}$ MES_{BDHP}). Since AES and MES depend on input levels, they have been estimated in the geometric mean of the data. Besides, in order to analyse if the elasticity estimates evaluated in the geometric mean are representative of the total sample, each of the AES and MES have also been estimated for each of the 183 vessels.

Based on the estimates in the geometric mean of the data derived from Y_1, GRT and BD are Allen complements. According to the MES, there is a qualitative asymmetry: while $MES_{GRTBD} < 0$, $MES_{BDGRT} > 0$, This can be interpreted in the following way. An exogenous limitation in BD would imply (in the long term) a reduction in the GRT (evidence of complementary behaviour). At the same time, however, the decline in BD induces the ratio GRT/BD to fall. Besides, GRT and BD behave as MES complements when a reduction in the BD happens (i.e. as a result of an input limitation program), while GRT and BD behave as MES substitutes when the reduced input is GRT (i.e. as a result of an alternative input limitation program). The estimates of AES_{HPBD}, MES_{HPBD} and MES_{BDHP} derived from Y_2 show significant quantitative and qualitative similarities. HP and BD are Allen complements, the asymmetry in MES persists, and, moreover, it reflects the same behaviour ($MES_{HPBD} < 0$ $MES_{BDHP} > 0$).

Table IX also summarises the range, the variance, and the percentage of positive, negative and almost zero AES and MES, considering the total sample and also a corrected sub-sample, in which, the elasticities of the non-regular vessels have been eliminated. With a variance of 8.08, the reported AES_{GRTBD} are rather variable. Ranging between [–9.65, 16.39] the AES_{GRTBD} is positive in the 70% of the point estimates. The variances of the MES for GRT and BD (i.e. 1.94 and 0.17) are considerably lower. Out of 183 estimates of MES_{GRTBD}, 81 are negative and 60 almost zero. That is, over 44% of the estimates point GRT and BD being Morishima complements, while over 33% estimates point almost no reaction in GRT as a consequence of the variation in BD. However, the 89% of the MES_{BDGRT} are positive, which implies that the asymmetry detected in the geometric mean of the data is extensible to the whole sample, and also to the corrected sub-sample. In the last one, the percentages of the most abundant categories (i.e. $AES_{GRTBD} < 0$, $MES_{GRTBD} < 0$, $MES_{BDGRT} > 0$) raise slightly. In the case of the elasticities derived from Y_2, the AES_{HPBD} range between [–24.3, 46.16] and are less variable than AES_{GRTBD}. However, while the variance of the MES_{HPBD} estimates is almost equal to $AES_{HPBD,}$ the variance of MES_{BDHP} (0.06) is considerably lower. The proportion of positive $AES_{GRTBD,}$ MES_{HPBD} and MES_{BDHP} is remarkable, which implies that in this case the mean value does not exactly reflect the regularities detected from the individual elasticicies.

In order to conclude with the taxonomy of substitutability and complementarity considering both, the AES and MES, Table X captures the percentage of vessels in the theoretically consistent and non-consistent typologies (we are grouping the last ones in VIO). In the 65% of the vessels GRT and BD are Allen complements and show an asymmetric behaviour for the MES. However in the case of the relationship between HP and BD, there are two predominant categories with similar percentages. In the 45% of the vessels, HP and BD are Allen and Morishima substitutes, while in the 40% the asymmetry of MES persists.

If we compare the estimates of AES and MES derived from Y_1 and Y_2, it seems that the possibilities of substitution between HP and BD are more evident than the ones detected between GRT and BD. Any case, the high proportion of estimates ranged between [–1,1] suggests that the substitution possibilities are limited. Besides, the detected asymmetry in MES suggests that an input limitation program based on the reduction in the boat days would be more efficient than an equivalent one limiting the GRT or HP.

5. SUMMARY AND POLICY IMPLICATIONS

Many regulation programs based on limitations of fishing effort have often failed due to the inefficient expansion of unregulated inputs. In this sense, prior to adopting a restrictive program, the production analysis can be useful to get an understanding of the internal structure of fishing effort and to evaluate the substitution possibilities among the inputs making it up. This can be especially useful in a fishery like the VIII division European anchovy where the EU Commission has imposed new fishing calendar restrictions due to shortcomings in TAC/licensing regulation system and the risk of population collapse.

A primal formulation has been used to estimate a translog production function for the main fleet operating in the VIII division European anchovy fishery (i.e. the Spanish purse seiner fleet) that includes fishing effort and fisherman's skill as production factors. The lack of the data necessary to evaluate any of the theoretical characteristics of skill (i.e. age, experience, education…) and the difficulties found to construct a credible subjective ranking of the captains led us to adopt a direct measurement approach. Thus, skill has been approximated by the ratio number of significant to number of total unloadings. Special attention has been paid to provide a rigorous empirical primal approach to test for the validation of fishing effort as an aggregate input before estimating the elasticity of substitution among the inputs making it up.

Two 3 input translog functions {$Y_1 = F_1$[GRT, BD, SK] & $Y_2 = F_2${HP, BD, SK]} have been estimated. Although both are statistically and economically acceptable, the *Cox* and *J* tests suggest that the model Y_1 is preferred to Y_2. The estimators are robust despite the detected non-normality of the residuals, and both estimated functions are monotonic and quasi-concave. The null joint hypothesis that [GRT, BD] and [HP, BD] are linearly separable from the skill [SK] has been accepted, which implies that: (1) Y_1 & Y_2 can be reduced to $Y_1 = F_1$\{[E_1(GRT, BD)], SK\} & $Y_2 = F_2$\{[E_2(HP, BD)], SK\}, where Y are the catches and E_1 and E_2 are two empirically validated consistent aggregator functions for fishing effort (2) the underlying functional structure for the macro functions F_1 & F_2 is a Cobb Douglas with translog micro functions for effort and skill. (3) the Allen elasticity of substitution between [GRT,HP,BD] and SK, is equal to one $\{AES_{GRTSK} = AES_{HPSK} = AES_{BDSK} = 1\}$.

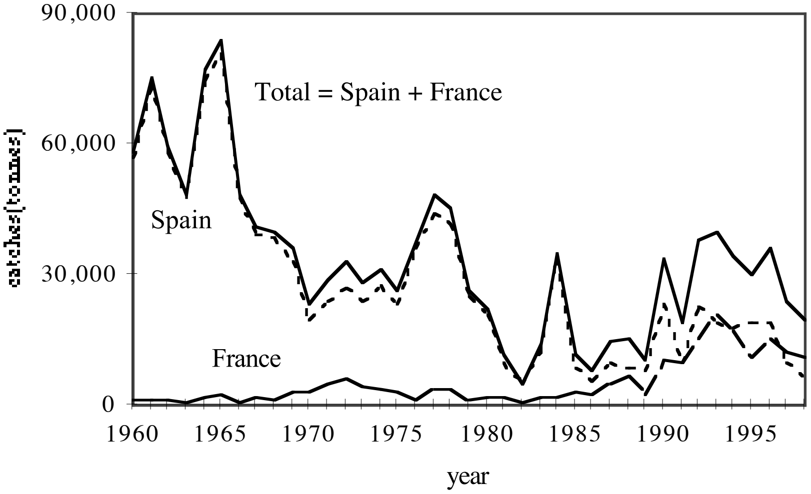
Despite the restriction (3), it is of course possible to estimate the elasticity of substitution between the inputs making up the two empirically validated proxies for fishing effort. Although it is not possible to conclude with an unambiguous taxonomy consistent with the estimates in the geometric mean and the estimates for each of the vessels in the sample, some predominant categories have been detected. GRT and BD behave as Allen complements ($AES_{GRTBD} < 0$) and show an asymmetric behaviour for the MES ($MES_{GRTBD} < 0$, $MES_{BDGRT} > 0$)) in most of the data points (65% of the vessels). In the case of HP and BD, the taxonomy is less clear. HP and BD are Allen and Morishima substitutes ($AES_{HPBD} > 0$, $MES_{HPBD} > 0$, $MES_{BDGRT} > 0$) in the 40% of the vessels, while the asymmetry of MES persists in the 40% ($MES_{HPBD} < 0$, $MES_{BDHP} > 0$).

On the basis of this empirical work fishermen could counteract a limitation in the boat days with horsepower increases, which could add economic inefficiency to the fishery. The substitution possibilities between HP and BD are higher than the ones detected for GRT and BD. Nevertheless, the high proportion of estimates ranged between [-1,1] indicates limited substitution possibilities between the inputs making up fishing effort. However this inelastic nature needs to be interpreted carefully, because even if the estimated elasticity of substitution is low, it is very difficult, with no price information, to determine how much substitution will in practice occur.

The detected asymmetry for the MES suggests that an input limitation program based on the reduction in the boat days would be more efficient than an equivalent one limiting the GRT or HP. Any case, different alternatives to the traditional input restrictions in a wide variety from ITQs to those based in co-management should be also considered to improve the fishery from a biological and economical point of view. Nevertheless, the complexities involved in obtaining a consensus between states can be an important barrier to achieving major changes.

-GRAPH 1-

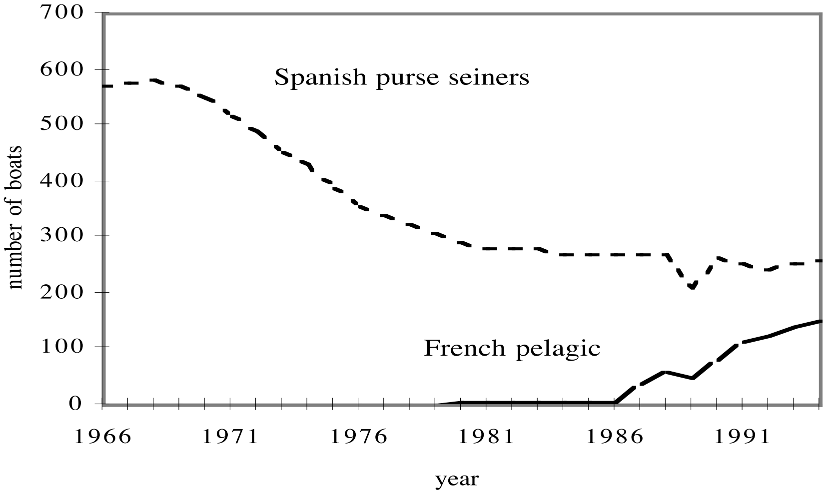
EVOLUTION OF ANCHOVY CATCHES



Source: AZTI. ICES.

-GRAPH 2-

THE EVOLUTION OF THE FLEETS



Source: AZTI. ICES, 1997.

- TABLE I -
SUMMARY OF CROSS SECTIONAL DATA

VARIABLE		TOTAL	MEAN	STANDARD DESVIATIO N
Boats (purse seiners)		250	-	-
Boats in sample	(N)	183	-	-
Harvest (tons)	(Y)	30,11	67.69	33.46
Tonnage	(G.R.T)	38,85	96.44	39.19
Horsepower	(HP)	185,64	479.65	195.94
Length (metres)	(L)	5,23	19.16	9.79
Boat days	(BD)	-	55.93	10.72
Year built	(SY)	-	1972.78	9.55

- TABLE II -
SUMMARY OF THE REGRESSION RESULTS

$Y_1[GRT, BD, SK]$				$Y_2[HP, BD, SK]$			
ESTIMATION METHOD	OLS	RLS	TLS	ESTIMATION METHOD	OLS	RLS	TLS
PARAMETER	ESTIMATED COEFFICIENT	ESTIMATED COEFFICIENT	ESTIMATED COEFFICIENT	PARAMETER	ESTIMATED COEFFICIENT	ESTIMATED COEFFICIENT	ESTIMATED COEFFICIENT
α_0	-4.1088	-6.7507	-10.1040	α_0	4.6449	6.6702	2.6773
	(-0.5129)	(-0.918)	(-1.5720)		(.4578)	(0.7635)	(.3252)
α_{GRT}	-3.2661*	-3.6380**	-4.2251**	α_{HP}	-3.5096	-5.1522**	-4.5842**
	(-2.2520)	(-2.7980)	(-3.7140)		(-1.8280)	(-3.129)	(-2.953)
α_{BD}	10.5740**	12.0450**	14.3870**	α_{BD}	7.4478	8.8851*	9.9974**
	(2.7400)	(3.1970)	(4.3640)		(1.8560)	(2.290)	(2.734)
α_{SK}	1.1907	0.4014**	0.2413*	α_{SK}	0.0830	.24114*	.12001
	(1.1630)	(3.3210)	(2.2820)		(0.0631)	(1.945)	(1.027)
β_{GRT2}	-0.1702	-0.1679	-0.1366	β_{HP2}	-0.0899	0.0202	0.0028
	(-1.4460)	(-1.4440)	(-1.3430)		(-.6057)	(0.1421)	(0.0215)
β_{BD2}	-1.9660**	-2.1338**	-2.4761**	β_{BD2}	-1.8332**	-1.9583**	-2.0249**
	(-3.7270)	(-4.0750)	(-5.4040)		(-3.458)	(-3.664)	(-4.019)
β_{SK2}	-0.0616	-0.0182	-0.0749*	β_{SK2}	-.11873**	-0.0787	-0.1158**
	(-0.6913)	(-0.4235)	(-1.9880)		(-2.4330)	(-1.828)	(-2.853)
β_{GRTBD}	1.2738**	1.3319**	1.4098**	β_{HPBD}	1.2713*	1.2772**	1.1844**
	(4.7480)	(5.3150)	(6.4310)		(1.946)	(3.830)	(3.768)
β_{GRTSK}	0.1114	0	0	β_{HPSK}	.27332	0	0
	(1.2760)				(1.2760)		
β_{BDSK}	-0.3205	0	0	β_{BDSK}	-.39114	0	0
	(-1.4490)				(-1.716)		
ADJUSTED R^2	$\overline{R}^2 = 0.71$	$\overline{R}^2 = 0.71$	$\overline{R}^2 = 0.72$	ADJUSTED R^2	$\overline{R}^2 = 0.70$	$\overline{R}^2 = 0.69$	$\overline{R}^2 = 0.70$
F TEST	F=52.43	F=66.08	F=32.61	F TEST	F=49.04	F=60.37	F=29.03

NOTES: The numbers in parentheses are t-ratios.

** Significant at 1%. Significant at 5%

-TABLE III-
THE ELASTICITIES OF PRODUCTION (ε_{ij})

$Y_1[GRT, BD, SK]$				$Y_2[HP, BD, SK]$			
PRODUCTION ELASTICITY	OLS	RLS	TLS	PRODUCTION ELASTICITY	OLS	RLS	TLS
ε_{GRT}	0.2024**	0.1936**	0.1916**	ε_{HP}	0.2130**	0.2074**	0.1926**
	(3.1342)	3.0493)	(3.3700)		(3.2998)	(3.2027)	(3.1549)
ε_{BD}	0.8394**	0.9092**	0.8865**	ε_{BD}	.90158**	.9860**	1.0000**
	(5.1888)	(5.7842)	(6.4358)		(5.5650)	(6.2316)	(6.7059)
ε_{SK}	0.4682**	0.4375**	0.3792**	ε_{SK}	3.2998**	0.3968**	0.3491**
	(8.8552)	(8.5588)	(7.9396)		(7.6570)	(7.2918)	(6.8063)

NOTES: The numbers in parentheses are t ratios.

** Significant at 1%.

The production elasticities can be calculated applying the formula:

$$\varepsilon_i = \frac{\partial LnY}{\partial Lnx_i} = \alpha_i + \sum_{j=1}^{n} \beta_{ij} Lnx_j$$

- TABLE IV-
SEPARABILITY TESTING RESULTS

SEPARABILITY TYPE		CONDITIONS	Y_1[OLS]		Y_2[OLS]		CRITICAL VALUES 1%	
							F	$\chi2$
STRONG	S [(i, BD), SK] [(i, SK), BD] [(BD, SK), i]	$\beta_{iBD}=\beta_{iSK}=\beta_{BDSK}=0$ $AES_{iBD}=AES_{iSK}=AES_{BDSK}=1$	$F_{3,173}$ 10.85	$\chi2_{(3)}$ 32.56	$F_{3,173}$ 7.33	$\chi2_{(3)}$ 21.9	3.78	3.07
WEAK LINEAR	LS1 [(i, BD), SK]	$\beta_{iSK}=\beta_{BDSK}=0$ $AES_{iSK}=AES_{BDSK}=1$	$F_{2,173}$ 1.99	$\chi2_{(2)}$ 3.99	$F_{2,173}$ 3.45	$\chi2_{(2)}$ 6.91	4.61	4.60
	LS2 [(i, SK), BD]	$\beta_{iBD}=\beta_{BDSK}=0$ $AES_{iBD}=AES_{BDSK}=1$	$F_{2,173}$ 11.49	$\chi2_{(2)}$ 22.98	$F_{2,173}$ 10.63	$\chi2_{(2)}$ 21.37	4.61	4.60
	LS3 [(BD, SK), i]	$\beta_{iSK}=\beta_{iBD}=0$ $AES_{iSK}=AES_{iBD}=1$	$F_{2,173}$ 16.03	$\chi2_{(2)}$ 32.07	$F_{2,173}$ 7.19	$\chi2_{(2)}$ 14.38	4.61	4.60
WEAK NON-LINEAR	NLS1 [(i, BD), SK]	$\alpha_i/\alpha_{BD}=\beta_{iSK}/\beta_{BDSK}=\beta_{i2}/\beta_{iBD}=\beta_{iBD}/\beta_{BD2}=0$ $AES_{iSK}=AES_{BDSK}\neq1$ & $AES_{iBD}=1$	$F_{3,173}$ 1.29	$\chi2_{(3)}$ 3.89	$F_{3,173}$ 2.21	$\chi2_{(3)}$ 6.65	3.78	3.07
	NLS2 [(i, SK), BD	$\alpha_i/\alpha_{SK}=\beta_{iBD}/\beta_{BDSK}=\beta_{i2}/\beta_{iSK}=\beta_{iSK}/\beta_{SK2}=0$ $AES_{iBD}=AES_{BDSK}\neq1$ & $AES_{iSK}=1$	$F_{3,173}$ 7.92	$\chi2_{(3)}$ 23.78	$F_{3,173}$ 5.45	$\chi2_{(3)}$ 16.4	3.78	3.07
	[NLS3] [(BD, SK), i]	$\alpha_{BD}/\alpha_{SK}=\beta_{iBD}/\beta_{iSK}=\beta_{BD2}/\beta_{BDSK}=\beta_{BDSK}/\beta_{SK2}=$ 0 $AES_{iBD}=AES_{iSK}\neq1$ & $AES_{BDSK}=1$	$F_{3,173}$ 5.17	$\chi2_{(3)}$ 15.53	$F_{3,173}$ 2.02	$\chi2_{(3)}$ 6.06	3.78	3.07

NOTE: i= GRT (for Y_1) or HP (for Y_2)

- TABLE V-

TESTS STATISTIC FOR HETEROKESDASTICITY AND NORMALITY OF THE RESIDUALS

Y_1[RLS]			Y_2[RLS]		
TEST	TEST STATISTIC	CRITICAL VALUE (5% LEVEL)	TEST	TEST STATISTIC	CRITICAL VALUE (5% LEVEL)
Harvey	$\chi^2_{(7)} = 6.177$	14.1	Harvey	$\chi^2_{(7)} = 9.605$	14.1
Glejser	$\chi^2_{(7)} = 3.750$	14.1	Glejser	$\chi^2_{(7)} = 9.898$	14.1
B.P.G.	$\chi^2_{(7)} = 2.973$	14.1	B.P.G.	$\chi^2_{(7)} = 4.572$	14.1
Jarque-Bera	$\chi^2_{(2)} = 167.26$	5.99	Jarque-Bera	$\chi^2_{(2)} = 252.56$	5.99

- TABLE VI-
REGRESSION DIAGNOSTIC [Y_1]

Y_1[RLS]

Obs	e	e*	ht	DF	DBα_0	DBα_{GRT}	DBα_{BD}	DBβ_{GRT2}	DBβ_{BD2}	DBβ_{GRTBD}	DFα_{SK}	DFβ_{SK2}
1	0.60	*2.07	*0.09	*0.68	*0.32	*0.35	*-0.45	*-0.16	*0.47	*-0.28	0.02	-0.04
24	0.43	1.48	*0.09	*0.48	0.04	*0.16	-0.09	0.09	*0.15	*-0.29	*0.17	0.11
43	0.19	0.76	*0.34	*0.55	0.03	0.08	-0.06	-0.07	0.07	-0.03	*0.29	*0.45
46	0.22	0.74	*0.10	0.25	0.07	0.11	-0.11	0.01	*0.15	*-0.17	-0.07	-0.09
50	-0.52	*-2.17	*0.36	*-1.64	*-0.99	*1.31	*0.47	*-0.86	*-0.20	*-0.83	0.00	0.01
59	0.37	-1.28	*0.09	*0.41	*0.29	-0.02	*-0.28	-0.07	*0.22	0.09	0.00	0.00
60	0.45	1.55	*0.09	*0.51	*-0.14	-0.10	*0.18	-0.05	*-0.22	*0.18	*0.15	*0.29
114	-1.27	*-4.46	0.04	*-0.87	0.10	*-0.27	0.02	-0.04	*-0.14	*0.43	*0.41	*0.45
119	-0.85	*-2.92	0.05	*-0.70	*-0.45	0.06	*0.43	0.03	*-0.37	-0.11	*-0.35	*-0.28
125	-0.33	-1.29	*0.28	*-0.81	-0.10	*0.23	0.01	*-0.60	-0.10	*0.32	*-0.20	-0.09
128	-0.64	*-2.13	0.03	-0.40	0.09	-0.07	-0.07	*0.18	0.10	-0.10	0.04	-0.04
129	0.63	*2.11	0.01	0.26	-0.10	0.13	0.05	*-0.16	-0.04	0.00	-0.02	-0.04
130	-0.83	*-2.81	0.02	-0.40	*0.26	-0.13	*-0.21	*0.18	*0.20	-0.02	0.12	0.11
136	-1.46	*-5.25	0.04	*-1.13	*0.34	*-0.19	*-0.27	*-0.34	0.12	*0.56	*0.30	*0.23
153	-0.65	*-2.17	0.02	-0.34	-0.05	-0.02	0.06	0.06	-0.05	-0.04	*0.19	0.14
175	-0.37	-1.32	*0.17	*-0.60	*-0.32	*-0.31	*0.43	0.09	*-0.47	*0.32	0.01	0.04
177	0.33	1.19	*0.18	*0.56	*0.15	*0.22	*-0.24	-0.01	*0.29	*-0.27	0.13	*0.19

Y_2[RLS]

Obs	e	e*	ht	DF	DBα_0	DBα_{HP}	DBα_{BD}	DBβ_{HP2}	DBβ_{BD2}	DBβ_{HPBD}	DFα_{SK}	DFβ_{SK2}
1	0.62	*2.10	*0.09	*0.68	*0.16	*0.29	*-0.38	-0.07	*0.47	*-0.27	0.02	-0.04
23	-0.18	-0.61	*0.15	-0.26	*-0.16	*0.20	0.05	-0.11	0.01	-0.11	0.01	0.00
24	0.48	1.65	*0.15	*0.71	-0.09	0.14	0.01	0.31	*0.24	*-0.56	*0.18	0.11
43	0.32	1.26	*0.35	*0.93	0.06	0.00	-0.07	0.13	*0.14	*-0.16	*0.49	*0.69
50	-0.42	-1.44	*0.14	*-0.58	*-0.47	*0.17	*0.42	0.01	*-0.27	*-0.22	-0.02	-0.01
58	0.17	0.57	*0.11	0.21	0.12	0.03	*-0.16	-0.04	0.14	0.01	0.00	0.01
59	0.40	1.33	*0.09	*0.42	*0.29	-0.02	*-0.31	-0.07	0.24	0.11	0.00	0.00
60	0.50	1.69	*0.09	*0.54	-0.08	-0.10	*0.16	-0.03	*-0.22	*0.16	0.14	*0.30
64	0.32	1.07	*0.09	0.35	0.15	0.08	*-0.22	-0.07	0.21	-0.02	0.13	0.08
81	0.66	*2.14	0.03	0.39	*0.19	0.06	*-0.26	-0.12	0.21	0.08	0.04	0.01
114	-1.55	*-5.32	0.02	*-0.67	*0.22	*-0.27	-0.07	0.34	0.10	-0.10	*0.35	*0.32
119	-0.70	*-2.32	0.06	*-0.58	*-0.26	-0.14	*0.39	0.16	-0.36	-0.03	*-0.28	*-0.21
125	-0.71	*-2.43	*0.12	*-0.91	-0.08	*0.15	-0.02	-0.43	*-0.17	*0.40	*-0.57	*-0.42
130	-0.81	*-2.63	0.02	-0.37	*0.23	-0.12	*-0.19	0.16	0.22	-0.07	0.14	0.12
136	-1.48	*-5.21	0.06	*-1.35	*0.53	*-0.20	*-0.47	-0.48	*0.06	*0.83	*0.37	*0.30
175	-0.45	-1.54	*0.13	*-0.61	*-0.24	*-0.23	*0.42	0.07	*-0.48	*0.19	-0.01	0.03

NOTE: (*)These entries exceeded the cutoffs /e*/>2, h>0.0874, /DFBETAS/>0.1478, /DFFITS/>0.4181.

-TABLE VII-
SUMMARY OF RLS REGRESSION DIAGNOSTIC

TYPE OF OBSERVATION	Y_1[RLS]		Y_2[RLS]	
	TOTAL	%TOTAL	TOTAL	%TOTAL
OUTLIERS	9	4.92	9	4.92
HIGH LEVERAGE OBSERVATIONS	19	10.38	24	13.11
INFLUENTIAL IN THE ESTIMATED PARAMETERS OUTLIERS	9	4.92	7	3.83
INFLUENTIAL IN THE PARAMETERS HIGH LEVERAGE OBSERVATIONS	8	4.37	11	6.01
INFLUENTIAL IN THE PREDICTIONS OUTLIERS	6	3.28	7	3.83
INFLUENTIAL IN THE PREDICTIONS HIGH LEVERAGE OBSERVATIONS	7	3.83	11	6.01
NUMBER OF OBSERVATIONS	183	-	183	-

-TABLE VIII-
MONOTONICITY AND QUASICONCAVITY TESTING RESULTS

[A] MONOTONICITY AND QUASICOCAVITY FOR EACH DATA POINT [SUMMARY]

Y_1[RLS]			Y_2[RLS]		
MONOTONICITY	TOTAL	%TOTAL	MONOTONICITY	TOTAL	%TOTAL
* Vessels $f_{GRT} > 0$	145	79.23	* Vessels $f_{HP} > 0$	148	80.87
* Vessels $f_{BD} > 0$	158	86.34	* Vessels $f_{BD} > 0$	17	90.71
* Vessels $f_{SK} > 0$	183	100	* Vessels $f_{SK} > 0$	183	100
VESSELS SATISFAYING QUASICONCAVITY	127	69.4	VESSELS SATISFAYING QUASICONCAVITY	105	57.38

[B] MONOTONICITY AND QUASICOCAVITY IN THE GEOMETRIC MEAN OF THE DATA

Y_1[RLS]	Y_1[RLS]
ESTIMATED BORDERED HESSIAN MATRIX	ESTIMATED BORDERED HESSIAN MATRIX

$$H_m\left[Y_1\right] = \begin{vmatrix} 0 & 130.7273 & 975.7695 & 69193.8 \\ 130.7273 & -2.5132 & 18.5850 & 153.862 \\ 975.7695 & 18.5850 & -43.4144 & 1148.45 \\ 69193.87 & 153.8626 & 1148.4540 & -112428 \end{vmatrix}$$

$$H_m\left[Y_2\right] = \begin{vmatrix} 0 & 27.5802 & 1058.137 & 62758.9 \\ 27.5802 & -0.04334 & 3.5954 & 29.4423 \\ 1058.137 & 3.5954 & -38.6304 & 1123.57 \\ 62758.90 & 29.4423 & 1123.578 & -135280 \end{vmatrix}$$

PRINCIPAL MINORS [M]	PRINCIPAL MINORS [M]
M_1 = -17,089.63	M_1 = -760.6710
M_2 = 7,878.173	M_2 = 287772.2
M_3 = -0.1037034E+13	M_3 = -0.3316781+11

-TABLE IX-
ALLEN (AES_{ij}) AND MORISHIMA (MES_{ij}) ELASTICITYS OF SUBSTITUTION

		Y_1[RLS]			Y_2[RLS]		
		AES_{GRTBD}	MES_{GRTBD}	MES_{BDGRT}	AES_{HPBD}	MES_{HPBD}	MES_{BDHP}
EVALUATED IN THE GEOMETRIC MEAN		-0.98	-0.29	0.55	–	–	–
		–	–	–	-0.73	-0.23	0.75
TOTAL SAMPLE	MIN	-9.65	-6.42	-2.45	-24.3	-22.33	-7.8
	MAX	16.39	9.99	1.75	43.16	46.9	2.28
	VAR	8.09	1.94	0.17	4.24	4.09	0.06
	% < 0	70	44	11	33	30	10
	% > 0	30	23	89	49	43	40
	% ≈ 0	0	33	0	18	27	50
	% (-1,1)	50	77	94	67	80	97
CORRECTED SAMPLE	MIN	-9.65	-6.42	-2.45	-24.2	-24.2	-2.3
	MAX	15.67	3.31	1.75	43.16	43.16	2.28
	VAR	7.87	1.50	0.18	5.37	6.34	0.09
	% < 0	73	44	10	25	30	11
	% > 0	27	21	90	46	43	50
	% ≈ 0	0	35	0	18	26	39
	% (-1,1)	48	76	95	67	80	95

-TABLE X-
THE TAXONOMY OF THE ALLEN AND MORISHIMA ELASTICITIES (%)

Y_1[RLS]	TIPOLOGY				
	$AES_{GRTBD}>0$ $MES_{GRTBD}>0$ $MES_{BDGRT}>0$	$AES_{GRTBD}<0$ $MES_{GRTBD}>0$ $MES_{BDGRT}>0$	$AES_{GRTBD}<0$ $MES_{GRTBD}<0$ $MES_{BDGRT}>0$	$AES_{GRTBD}<0$ $MES_{GRTBD}>0$ $MES_{BDGRT}<0$	**VIO^{+}**
TOTAL SAMPLE	20.21	3.82	**65**	0	10.38
CORRECTED SAMPLE	18.11	1.57	**72.44**	0	7.87

Y_2[RLS]	TIPOLOGY				
	$AES_{HPBD}>0$ $MES_{HPBD}>0$ $MES_{BDHP}>0$	$AES_{HPBD}<0$ $MES_{HPBD}>0$ $MES_{BDHP}>0$	$AES_{HPBD}<0$ $MES_{HPBD}<0$ $MES_{BDHP}>0$	$AES_{HPBD}<0$ $MES_{HPBD}>0$ $MES_{BDHP}<0$	**VIO**
TOTAL SAMPLE	**45.35**	1.63	**39.94**	0	13.11
CORRECTED SAMPLE	**43.80**	2.85	**40.95**	0	12.38

NOTES: The number of boats in the corrected samples is Y_1 (N'=127) and Y_2 (N'=105).

$^{+}$ VIO= [AES_{GRTBD} >0, AES_{GRTBD} <0 AES_{GRTBD} <0], [AES_{GRTBD} >0, AES_{GRTBD} <0 AES_{GRTBD} >0] and [AES_{GRTBD} >0, AES_{GRTBD} >0 AES_{GRTBD} <0],

5.REFERENCES

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NOTES

· This study has received financial support from the Spanish Ministry for Education and Science, DGICYT MAR96-0470.

[*] We wish to express our thanks to AZTI and in particular to Andrés Uriarte and Iñaki Artetxe for their assistance in obtaining the data required in the preparation of this study. We are especially grateful for suggestions and support given by T. Bjørndal, L. Cromar, N. Dávila, C. Gallastegui, B. Iraizoz, A. Uriarte, M. Varela, M. Viladrich and J.M. Zarzuelo. The authors are particularly grateful to an anonymous referee for a through and constructive review which substantially improved the paper. The authors are also grateful to conference participants at Asepelt 1998 (Bilbao (Spain)), EAFE 2000 (Esberg, (Denmark)) and IIFET 2000 (Corvallis, (USA)) and Seminar at CEMARE (Department of Economics (Portsmouth University). All errors and opinions are the author's responsibility.

[2] These agreements stipulate certain rules for the co-existence of different fishing techniques, an international closed season is observed from December 1st to January 30th and fishing is reserved strictly to the purse seine fleet from March 20th to May 31st.

[3] More rigorously, Acheson (1981) and Thorlindsson (1988) identified the skipper skill with: 1) the ability to accurately navigate to find the best grounds. 2) the good knowledge of the ocean, such us its currents, depths, and types of bottom, 3) the good knowledge of the species o concern. 4) the ability to read the sea and its ecological environment. 5) the willingness of the skipper to search independently and to take calculated risks and 6) the ability of a skipper to lead and manage the crew.

[4] Although they could explain TE with the years experience in fishery and education level, the consistent differences in productivity found for two similar captains (same age, race, education and experience and operating nearly identical vessels) suggests there are likely to be other possible components (i.e. motivation) of managerial skill.

[5] The 183 vessels included in the sample belong to more than 30 harbours. We had several reviews with people working in the sector for long a period of time and found that while it was easy for them to have an opinion of the skill or managerial ability of the captains of their own harbour and close ones, the difficulties arose when we asked for vessels belonging to distant harbours. Consequently, instead of constructing a subjective index based on answers of different people we decided to adopt the direct approach.

[6] After consulting with fishermen, an unloading of more than 2,500 kg is considered to be significant.

[7] Due to the high correlation among tonnage and length (0.9) and the fact that this data was not available for the %10 of the vessels, the length has been excluded.

[8] Although the shipbuilding year (SY) could introduce an element of vintage capital (Bjørndal, 1989), neither it, nor the material seem to make a priori any significant contribution to the harvest. Besides, as both variables are in practice irrelevant to analyse substitution possibilities among inputs, we decided to eliminate them.

[9] Unfortunately this paper excludes the stock variable because it is cross-sectional from one year. Consequently we cannot address the question of whether a fishing effort aggregator exists that is consistent across all stock sizes.

[10] Weak separability requires the marginal rates of technical substitution (MRTS) between all pair of variables in a particular group (such as effort) to remain independent of changes in the levels of inputs, which are not in that group. Weak separability of technology is a necessary and sufficient condition for the existence of an aggregate input (fishing effort), while homotheticity is a necessary and sufficient condition for the validity of sequential optimisation. Homothetic separability exists if production technology is weakly separable and the aggregator function is linear homogeneous.

[11] Although several types of separability exist, the relevant type for aggregation is weak separability. Weak separability requires that the marginal rates of technical substitution between all pair of variables in a particular group (such us effort) are independent of changes in the levels of variables not in that group.

[12] f_i is the logarithmic marginal product for input i.

$$f_i = \varepsilon_i \frac{Y}{x_i} = \frac{\partial LnY}{\partial Lnx_i} \frac{Y}{x_i} = \left[\alpha_i + \sum_{j=1}^{n} \beta_{ij} Lnx_j \right] \frac{Y}{x_i}$$

Where ε_i is the production elasticity for input i.

[13] Following a primal approach the AES can be estimated applying the formula:

$$AES_{ij} = \frac{\sum_i x_i f_i}{x_i x_j}\frac{F_{ij}}{F}$$

where F is the determinant of the bordered Hessian matrix and F_{ij} is the cofactor of f_{ij} and F.

$$F = \begin{bmatrix} 0 & f_1 & f_2 & \cdots & f_n \\ f_1 & f_{11} & f_{12} & \cdots & f_{1n} \\ f_2 & f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_n & f_{n1} & f_{n2} & \cdots & f_{nn} \end{bmatrix}$$

[14] Driscoll et al. (1992) propose rules for determining the minimal number of parameters required to maintain flexibility in production models given different hypothesis such us homogeneity, homotheticity, weak separability, homothetic separability or strong separability. Their results show that flexible functional forms can lose flexibility after imposing some kind of restrictions on the structure.

[15] f_{ii} is the second direct partial derivative for input i.

$$f_{ii} = \left[\beta_{ii} + \left(\alpha_i + \sum_{j=1}^{n}\beta_{ij} Lnx_j - 1\right)\left(\alpha_i + \sum_{j=1}^{n}\beta_{ij} Lnx_j\right)\right]\frac{Y}{x_i^2} = \left[\beta_{ii} + \left(\varepsilon_i - 1\right)\varepsilon_i\right]\frac{Y}{x_i^2}$$

[16] f_{ij} is the second cross partial derivative for input i respect to input j.

$$f_{ij} = \left[\beta_{ij} + \left(\alpha_i + \sum_{j=1}^{n}\beta_{ij} Lnx_j\right)\left(\alpha_j + \sum_{i=1}^{n}\beta_{ij} Lnx_i\right)\right]\frac{Y}{x_i x_j} = \left[\beta_{ij} + \varepsilon_i \varepsilon_j\right]\frac{Y}{x_i x_j}$$

[17] The two-factor Hicksian elasticity of substitution (σ) is a measure of the curvature of the isoquant and gives complete qualitative and quantitative comparative-static information.

$$\sigma = \frac{d(x_2 / x_1)}{d(f_2 / f_1)}\frac{f_1 / f_2}{x_2 / x_1}$$

[18] Only in the case of a CES production structure AES does serve as an appropriate measure of the curvature of the isoquants.

[19]Following a primal approach, MES can be defined as

$$MES_{ij} = \frac{f_j}{x_i}\frac{F_{ij}}{F} - \frac{f_j}{x_j}\frac{F_{jj}}{F}$$

where F is the determinant of the bordered Hessian matrix and F_{ij} is the cofactor of f_{ij} and F.

[20] Following Chambers (1988)

$$MES_{ij} = \frac{f_j x_j}{\sum f_i x_i}(AES_{ij} - AES_{jj})$$

[21] To face up that "*data mining*" is likely by chance to uncover significant t statistics, Lovell (1983) offers a rule of thumb for deflating the exaggerated claims of significance. When a search has been concluded for the best k out c candidates explanatory variables, a regression coefficient that appears to be significant at the level α should be regarded as significant only at level α'= (c/k) α. Consequently, in our case the variables found significant at 1% and 5% ought to be considered significant only at 1.3% and 6.6%.

[22] The respective values of the Cox statistics under the hypothesis that the correct set of regressors is the one in Y_1 (GRT, BD, SK) or the one in Y_2 are q=–1.1 and q=–5.8. Taking into account that the statistics is asymptotically distributed as a standard normal random variable, we accept the hypothesis that the set of regressors contained in Y_1 is the correct one, while reject the set contained in Y_2.

[23] The Y_1 regression produces an estimate of λ = 1.7. The λ concerned with Y_2 is 4.19. Consequently, the conventional t test let us conclude that Y_1 should be rejected in favour of Y_2.

[24] Although OLS estimators (or RLS in the case of a priori expected null hypothesis acceptation) are the best linear unbiased ones and the conventional tests are *asymptotically* justified, some authors argue that neither of the points is very compelling to justify the use of OLS (or RLS) estimators under conditions of non-normality of the residuals. Instead of these they advocate the use of robust estimation techniques (see Judge et al. (1988) for a complete summary of robust estimation methods.

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[25] Despite the fact that this study is only concerned with the separability of inputs making up effort from skill, that is to say [(GRT,BD), SK] and [(HP,BD), SK] linear or non-linear separability types (Table IV), in order to show the complete picture, tests for all types of separability have also been included.

[26] F test is not reliable to test for non-linear separability.

[27] Although, having rejected complete global separability and having accepted one type of linear separability (LS1) no other separability type can exist ((B&C), 1973(b)), for completeness we are also including NLS tests.

[28] The functions Y_1[OLS], Y_2[OLS], Y_1[TLS], Y_2[TLS] are also monotonic and quasi-concave in the geometric mean of the data.