Measuring efficiency in demersal trawlers using a frontier production function approach

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Abstract

A main feature of European fisheries management is a programme to reduce the level of capacity in EU fisheries. A criticism of such programmes is that the remaining fleet can increase their level of fishing effort thereby reducing the benefits from the programme. The extent to which the remaining fleet is capable of increasing effort is partly dependent upon the current level of efficiency of the fleet. If the current fleet is largely operating on an inefficient basis, then effort can increase through reducing the inefficiencies.

In this study, the level of efficiency of individual demersal trawlers operating in the English Channel is estimated using a stochastic frontier production function. The causes of any inefficiencies are explained based on the characteristics of the boats making up the fleet. Measures are undertaken to distinguish under-utilisation of capacity from technical inefficiency.

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Introduction

An assumption that often underlies input controls in fisheries management is that a group or sub-sets of boats can be identified that are homogeneous in terms of effort. If this assumption is incorrect there is a danger that input controls such as decommissioning may remove the most inefficient boats from the fishery. Consequently the reduction in effective effort may not be as great as suggested by the reduction in the fleet's physical capacity. Further, the remaining fleet may have the potential to increase fishing effort through exploiting increases in technical efficiency, thus thwarting the original policy objective.

The measurement of efficiency of fisheries has to date mainly been undertaken through examination of production functions. Whilst this is a useful approach it only indicates average performance of a given fleet. Given the application of input controls to fisheries a more useful investigation is therefore to consider the productivity differences between firms. In other words, to consider the relative performance of individual boats operating in a fishery. This can be achieved through stochastic production frontier analysis.

In this paper, the stochastic production frontier technique is applied to data for a sub-set of boats from the English Channel demersal trawl fleet. The relative efficiency of each boat in the data is estimated. The analysis also examines the homogeneity assumption of effort by considering whether there are similarities in technical efficiency between boats that undertake similar activities.

Whilst measures of boats relative technical efficiency are interesting from a policy perspective, it is also important to have information on the source of inefficiency between boats. The source of inefficiency is explained by a variable (or variables) that was not expressed in the estimation of the stochastic production frontier. In particular the effects of specialisation on efficiency is also examined by comparing multi-purpose boats with specialised boats. The implications of differences in technical efficiency for fleet reduction programmes are also examined.

Technical efficiency

A production function defines the relationship between the level of inputs and the resultant level of outputs. It is estimated from observed outputs and input usage and indicates the average level of outputs for a given level of inputs (Schmidt 1986). However, it does not take into account differences in efficiency in the use of the inputs.

The level of efficiency of a particular unit can be characterised by the relationship between observed production and some ideal or potential production (Greene 1993a). This is consistent with Farrell's definition of technical inefficiency (Farrell 1957), demonstrated in figure 1. In this figure, the firm is producing a given level of output using combination of inputs depicted as point A. However, a perfectly efficient could produce the same level of outputs (depicted as the isoquant II) by using the same proportion but a lower level of inputs, depicted as point B. The comparison of input use at B and A forms the basis of the measure of the Farrell technical efficiency (*TE*), defined as:

$$TE = OB / OA \quad (1)$$

TE equals 1 for perfectly efficient firms whose input combinations are on the isoquant II. Technical efficiency approaches zero the further away a firm is located from the isoquant since the amount of inputs per unit of output becomes indefinitely large (Farrell 1957)[1].

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[1] It is important to note that any points along the isoquant are not necessarily the most profitable factor combination . This only occurs when the isocost line PP, in Figure 1 is tangential to the isoquant line, i.e. at C. However this is an allocative efficiency problem and requires information on factor input prices and output prices. For a full exposition see Farrell (1957), Heathfield and Sören (1987) or Greene (1993a).

Measurement of technical efficiency is therefore based upon deviations of observed output from a frontier isoquant.

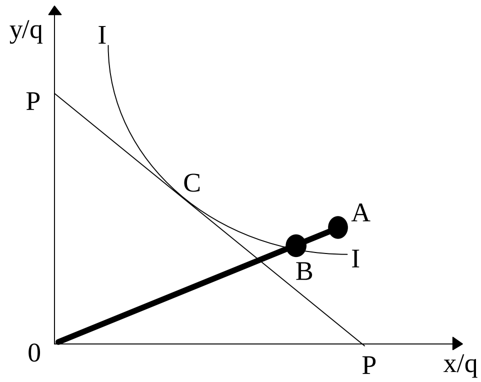


Figure 1 Diagrammatic exposition of Farrell's technical efficiency

Empirical measurement of technical efficiency falls into two principal areas - stochastic techniques and data envelopment analysis techniques (DEA)[1]. Both techniques have advantages and disadvantages. Econometric stochastic techniques permit statistical testing of hypotheses and attempt to distinguish noise from the effects of inefficiency. However, non-parametric approaches such as DEA are less prone to mis-specification of the functional form (Wu 1996)[2].

Stochastic techniques start with a basic production frontier model, such as:

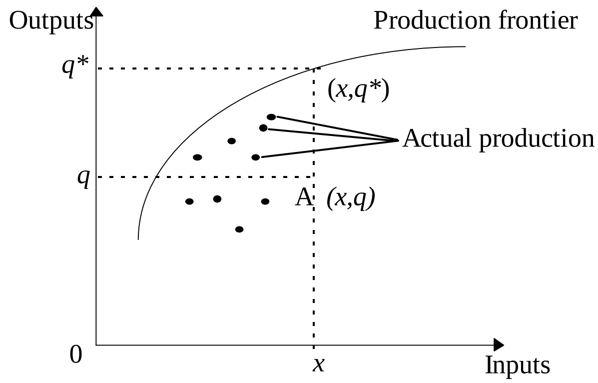
$$ln\, q_j = ln\, \beta_0 + \sum_i \beta_i\, ln\, x_{i,j} + v_j - u_j \quad (2)$$

where q_j is the output produced by firm j, $x_{i,j}$ is the level of factor input i by firm j, β_0 is a constant term, β_i are coefficients, v_j is the stochastic error term (assumed to have a normal distribution with a mean of zero and variance σ^2_v) and u_j is the estimate of the Farrell technical inefficiency of firm j (assumed to be a non-negative truncation of normal distribution with mean μ distribution and variance σ^2_u). Both v_j and u_j are independent of each other.

Following Farrell's example, the term u_j represents the extent by which the input level of a firm is above a given isoquant, where the isoquant represents maximum attainable output.

1 DEA is a linear programming technique.
2 For comparative review of the two approaches see Schmidt, 1986.

Hence, each firm's actual production point lies on (if perfectly efficient) or below the frontier (figure 2).



Source: Wu 1996.

Figure 2 The production frontier and technical efficiency

To estimate the stochastic production frontier an appropriate functional form is assumed (i.e. Cobb-Douglas or Translog production function) and the parameters of the model β_0, β_i, σ^2_v and σ^2_u. are estimated by maximum likelihood estimation. The estimation of the maximum value of the logged likelihood function is based on a joint density function for the split error term v_j-u_j (Stevenson 1980). From this technical efficiency can be calculated for the individual firm (Jondrow *et al* 1982, Battese and Coelli 1988). Hence, given that the production of each firm j can be expressed as:

$$q_j = (\prod_i x_i^{\beta_i})e^{-u_j} \qquad (3)$$

while the efficient level of production is defined as:

$$q^* = (\prod_i x_i^{\beta_i}) \qquad (4)$$

then the technical efficiency can be given by:

$$TE = \frac{q_j}{q^*} = \frac{(\prod_i x_i^{\beta_i})e^{-u_j}}{(\prod_i x_i^{\beta_i})} = e^{-u_j} \qquad (5)$$

Technical efficiency of the *j*th firm is therefore a relative measure of its output as a proportion of the corresponding frontier output. In Figure 2 technical efficiency therefore equals q/q^* at point A (Wu 1996).

In contrast to the estimation of the production function, the estimation of the production frontier measures the relative efficiency of certain groups or set of practices. This approach also allows the possibility that the characteristics or variables that explain inefficiency can be identified.

The statistical or econometric estimation of technical inefficiency has been developed and applied extensively to a range of industries. For example, technical efficiency of has been estimated for manufacturing (Harris 1993, Sheehan 1997) and steel production (Wu 1996), as well as a range of agricultural activities e.g. dairy farms (Battese and Coelli 1988, Hallam and Machado 1996, Jaforullah and Devlin 1996) and crop farms (Deff, Garcia and Nelson 1993, Heshmati and Cumbhakar 1997). Comprehensive reviews of the techniques have been undertaken by Schmidt 1986, Greene 1993a).

Production functions, production frontiers and technical efficiency in fisheries

A number of studies have estimated the relative contribution of the factors of production through estimating production functions at either the individual boat level or total fishery level. These include Cobb-Douglas production functions (Hannesson 1983, Robinson and Pascoe 1996), CES production functions (Campbell and Lindner 1990, Campbell 1991, Robinson and Pascoe 1996), and translog production functions (Squires 1987, Campbell 1991, Pascoe and Robinson 1998). A number of alternative functional forms of the production function have also been used. Dupont (1991) used a normalised quadratic restricted profit function to determine elasticities of substitution between key inputs. Staniford (1988) and Greenberg and Herrmann (1993) used linear production functions, with catch a linear function of a number of inputs.

Earlier attempts at examining variations in technical efficiency of fishing boats have focused on the estimation of relative fishing powers. Fishing powers are a measure of the relative efficiency of vessels operating in a fishery. For example, a boat with a fishing power of 1.2 would be expected, on average, to catch 20 per cent more per unit of nominal effort (for example, per hour) than a boat with a fishing power of 1, if both fished in the same area at the same time. If both boats fished for the same amount of time, the effective effort of the first boat would have been 20 per cent higher than the other. The effective effort of a vessel is the product of the fishing power and the nominal measure of effort of a vessel.

Fishing powers are estimated by comparing catch per unit of nominal effort of the boats operating in the fishery[1]. A number of studies have been undertaken to determine the relative contributions to fishing power of the main physical and non-physical components of the fishing operation. These have generally involved regressing a number of potential explanatory

[1] This can be done through either an iterative processes (see Gulland 1956, Haynes and Pascoe 1988) or regression analysis (see Hilborn and Walters 1992).

variables against the estimated fishing powers. Most of these studies have found that fishing power is most highly correlated with engine power (e.g. Gulland 1956, Beverton and Holt 1957, Hovart and Michielsen 1975, Houghton 1977, Large and Banister 1986). However, crew size, age, tonnage and the amount of gear used have also been found to be important factors affecting fishing powers in some fisheries (e.g. Zijlstra and de Veen 1963, Buchanan 1973, Taylor and Prochaska 1986, Dann and Pascoe 1994, Jaffry 1995). The examination of factors affecting fishing powers can provide valuable information to managers, especially if some form of input control management system is planned. For example, it may be pointless limiting boat size if engine power is the main factor affecting the fishing power of a boat. In such a case effort could still increase in the fishery, provided it was economically feasible, through using larger engines.

The observable physical attributes of the vessels do not account for all of the variation in fishing powers between vessels. The contribution of these factors vary significantly between fisheries and in some case between species in the same fishery. The unexplained variation in fishing powers can be separated into three main components - unmeasurable differences in on-boat technology, variations in skipper and crew skill, and 'luck' (or purely random variations that cannot be attributed to any factor).

Several authors have suggested that the ability of the skipper may be the single key factor affecting the fishing power of a boat. Crutchfield and Gates (1985) found that skipper skill was perhaps the most important single contributor to fishing powers, with 'highliner' skippers earning as much as seven to ten times the annual earnings of 'lowliner' skippers operating similar boats. Comitimi and Huang (1967) found that in the Pacific halibut fishery 'excellent' operators could consistently catch 20 per cent more than an 'average' operator given the same boat characteristics.

In contrast, some authors (for example, Hilborn and Ledbetter 1985) have found that most of the unexplained portion of fishing powers is attributable to 'luck'. A boat that had a 'lucky' season would be estimated as having a higher fishing power than it could maintain in the longer term. The greater the element of 'luck' in a fishery, the more difficult it is to standardise effort using fishing powers.

An advantage of the estimation of technical efficiency using a stochastic production frontier approach rather than fishing powers is that the 'luck' component can be separated out as the stochastic component. As a result, differences in technical efficiency are due to the physical inputs used in the production process, and the way in which they are employed. Provided that all inputs can be identified and incorporated into the frontier model, any variations in efficiency are due to the skill of the skipper in using these inputs efficiently. Despite this apparent advantage, only one previous study of technical efficiency in the fishing industry could be identified in the literature. Kirkley, Squires and Strand (1995) estimated technical efficiency of 10 boats in the mid Atlantic sea scallop fishery using the stochastic production frontier technique. They found that a relatively wide level of technical efficiencies could be maintained over a wide range of input levels and resource conditions.

English channel demersal trawl fleet

The Channel fishery consists of a wide variety of fishing activities that are aimed at targeting a variety of species. Approximately 4000 boats operate within the English Channel, over half of which are UK boats. UK boats broadly fall into 7 gear types: beam trawl, otter trawl, pelagic/mid-water trawl, dredge, line, nets and pots. To date, 74 separate sub-fisheries or métiers have been formally classified in the English Channel defined by reference to fishing technique, area fished, season, and the subsequent composition of the catch (Tétard, Boon *et al* 1995). Of these, 35 are attributable to UK waters. The otter and beam trawl métiers are described in table 1.

Table 1 UK otter and beam trawl métiers in the English Channel

Métier code	Gear used	Area	Inshore/ Offshore	Main species in order of quantity landed
U1-1	Otter trawl	West	Both	Whiting, cuttle, plaice, lemon sole, angler
U1-2	Otter trawl	East	Both	Plaice, whiting, sprat, cod, sole
U2-1	Beam trawl	East	Offshore	Plaice, sole, cuttle
U2-2	Beam trawl	West	Offshore	Cuttle, plaice, sole, angler
U2-3	Beam trawl	West	Inshore	Angler, cuttle, plaice, sole

Source: Tétard, Boon *et al* (1995).

Beam trawlers operate throughout the year, although the most intense period is during the summer. Similarly otter trawling takes place all year round although otter trawls are slightly more sensitive to climatic and tide conditions. For many of the smaller otter trawlers fishing during the winter will therefore be irregular. Both beam and otter trawlers target quota species. Beam trawlers key target species includes sole, angler fish, cuttle-fish and plaice. Otter trawlers also target these species. However, because they also tend to be opportunistic (i.e. dependent on market conditions and stock availability) their catch composition is relatively varied, including rays, bass, mackerel etc. (Tétard, Boon *et al* 1995).

Both beam and otter trawlers are subject to output controls. To target quota species boats are required to hold a category A licence issued by MAFF endorsed for catch quota species (pressure stocks). Total fishery catch quotas for several species (including sole and plaice) are imposed by the European Union. In addition, beam trawlers catches are also subject to various input controls by the UK government via MAFF (see Pascoe and Robinson, 1998).

Little previous research has been undertaken in examining the factors that affect the relative efficiency of demersal trawlers operating in the Channel. Houghton (1977) examined the fishing powers of trawlers in the western English Channel between 1965 and 1968. However, the results of this earlier study are not likely to be relevant today. Large (1992) demonstrated that fishing powers of boats operating in the western Channel have changed considerably over time, but did not attempt to quantify the factors affecting these changes. Jaffry (1995) demonstrated that engine power and boat size are the main physical characteristics contributing to the fishing power of otter trawlers in the Channel, but considerable variability in fishing powers was still unexplained by the model. Robinson and Pascoe (1996) examined the contribution of engine power and boat size to relative catch rates of UK beam trawlers operating in the Channel. This work was further developed by Pascoe and Robinson (1998), who demonstrated that beam length and hours fished per day are also important factors in determining relative catch rates of beam trawlers.

Data

Data were available from log book records on the characteristics of inputs and outputs for the English Channel over a four year period (1992 to 1995). Log book data are collected by MAFF on quota species only. There is no requirement to record catch of non-quota species and therefore a voluntary record system operates for these species. A degree of caution therefore has to be exercised in terms of interpreting the available records. However, given that the main part of the catch composition for both otter and beam trawl is predominately quota species such as sole and plaice it was assumed that catch records gave a fairly accurate picture of the main value of these boats catch composition. In the data, boats tended to record both quota and non-quota species. Where non-quota catch had been recorded it was assumed that these would be fairly accurate given that there was no requirement to record this catch. In addition to this, the possibility that quota controls may be extended to currently non-quota species means that there is an incentive for fishers to record non-quota catch accurately to establish a track record. Hence, whilst some species may not have been recorded, this is likely to constitute only a small proportion of the catch.

A total of 457 boats had recorded catch in either one or all of the otter and beam trawl métiers (U1.1, U1.2, U2.1, U2.2 and U2.3 respectively) over the four year period. However, for many boats only a relatively small number of observations were available. An assumption was made that the reliability of the data for each boat was proportional to the number of observations in the data. Only boats that had recorded catch for at least three of the years and for at least four months in each year were included in the analysis. Sixty-three boats satisfied these criteria. Thirty-three of these boats had recorded catch exclusively from the beam trawl métiers. Three of the boats had exclusively recorded catch from the otter trawl métiers. Thirty-two boats had recorded catch from both the otter and beam trawl métiers.

Descriptive statistics for the subset of the sample (n=63) are presented in Table 2. Boats were categorised by principal activity based on their effort allocation (hours fished) between the otter or beam trawl métiers. Boats that spent 100 per cent of their time in beam trawl métiers were categorised as 'Beam trawl only' in table 2. Two other categories ('Mostly beam trawl' and 'Mostly otter trawl') were defined on the basis of the proportion of effort in the respective métiers. For example, a boat that mostly beam trawled meant that it spent between 50 to 99 per cent of hours fished in the beam trawl métiers. The rest of its time was spent in the otter trawl métiers. As only three boats spent 100 per cent of their time in the otter trawl métier, these boats were defined as mostly otter trawl for the purposes of Table 2.

Table 2 Descriptive statistics for sample boats

Characteristic	Beam trawl only (n=33)		Mostly beam trawl (n=18)		Mostly otter trawl (n=17)	
	Mean	STD	Mean	STD	Mean	STD
Year built	1969	8.41	1972	14.40	1980	11.99
Crew size	6	0.81	4	1.76	3	1.23
Gross registered tonnage	105.4	42.62	56.1	43.24	24.5	20.10
Engine size (kW)	482.4	215.54	271.8	148.94	148.5	41.79
Overall length (metres)	26.6	3.27	20	6.70	13.2	3.35
Width (metres)	6.53	0.61	5.81	0.92	4.73	0.73

From table 2 it can be seen that the largest and oldest boats are beam trawlers. In deed the beam trawl fishery contains many of the largest and oldest fishing vessels operating in the Channel (Pascoe, Robinson and Coglan 1997). Hence, this subset of beam trawlers is not out of line with what is observed in the true population. As would be expected the smaller boats of in the sample are those whose principal activity was otter trawling. The mean age of these boats is 18 years. Whilst there does appear to be a trend between size and age it is likely that this relationship is spurious[1]. However the relationship between size of boat and number of crew is correlated, i.e. the bigger the boat the greater the number of crew.

The model specification and results

Since the UK English Channel fishery is a multi-species fisheries, output is measured in terms of its value. The relationship between the total value of catch and boat inputs was examined using the translog functional form of the production frontier. In general terms this can be expressed as

$$\begin{aligned} \ln V_{j,a,t,,y} &= \beta_0 + \sum_i \beta_i \ln X_{j,i} + \frac{1}{2}\sum_i \sum_k \beta_{i,k} \ln X_i \ln X_k \\ &+ \sum_{y=2}^{l} \delta_y Y_y + \sum_{t=2}^{m} \gamma_t M_t + \sum_{a=2}^{n} \lambda_a A_a - u_j + v_j \end{aligned} \quad (6)$$

[1] Nautilus Consultants (1997) found that many operators who decommissioned their boats in the South West under the MAFF funded decommission scheme used the funds to purchase new boats under 10 metres overall length. However, this has mostly occurred in more recent years so would not be influencing the observed trend in the data. The greatest influx of small boats in the sample occurred in 1990, before the current decommissioning scheme would have had an impact.

where $V_{j,a,t,y}$ is the value of catch of boat j in métier a, month t and year y, X_i and X_k are the boat inputs to the production process, and Y_y, M_m and A_n are the year, month and area (métier) dummy variables. As noted above, the error term is separated into two components, where v_j is the stochastic error term and u_j is the estimate of the technical inefficiency. Both the Cobb-Douglas and the CES production functions are special cases of the translog production function (Thomas 1993). The model takes the form of the Cobb-Douglas production function if all $\;_{i,j} = 0$ (Greene 1993b) and is a linear approximation of the CES production function if $\;_{i,i} = \;_{j,j} = 0.5\;\;_{i,j}$ (Campbell 1991). Hence, it is a more flexible functional form, and is not constrained by the assumptions underlying the Cobb-Douglas and CES production functions.

The inputs selected for the production function included boat length, engine power and number of hours fished. Pascoe and Robinson (1998) found these inputs to be significant in explaining most of the variation in catch per unit of effort between boats in the beam trawl fishery. In addition, Pascoe and Robinson (1998) also included beam length as a key input. However, this model includes both beam trawlers and otter trawlers. As there was no available comparable measure of the amount of gear used in the otter trawl fishery, it was decided to exclude the gear use variable from the model. While the omission of this variable may result in the effects of variations in gear use being incorporated into the technical efficiency measure, Pascoe and Robinson (1998) found that the level of gear use was highly correlated with boat size and engine power. Hence it is likely that the effects of gear use will largely be captured by these variables.

The number of hours fished allows the effects of capacity under-utilisation to be separated from technical inefficiency. Failure not to take account of the fact that boats may operate at level less than full capacity will result in under-utilisation of resources to be interpreted as inefficiency (Harris 1993).

The dummy variables in the model incorporate the effects of variation in stock abundance and species composition on the value of catch. The year dummy variables incorporate the effects of fluctuations in stock abundance between years. The monthly dummy variables incorporate the effects of seasonal variation in stock abundance and also catch composition. The métier dummy variables incorporates the effects of the different catch compositions when using the different gear types, as well as the differences in abundance and catch composition between different areas of the fishery. As there can only be *n-1* dummy variables (to avoid problems of collinearity), no dummy variable was included in the model for 1992, January and U2.3.

The model was estimated using the panel data specification of the FRONTIER procedure in LIMDEP (Greene 1995). This uses a Maximum Likelihood Estimation procedure to estimate the production frontier. Ordinary Least Squares are used to provide starting values for the non-linear estimation procedure. The procedure also estimates the means and standard deviations of the u and v components of the error term. From these, the technical inefficiency of the individual boats can be estimated, assuming a given distribution of the inefficiency parameter. Three distributions are generally used - a truncated distribution, half normal distribution and exponential distribution. The truncated distribution is a more general specification as it allows for a non-zero mean of the stochastic error term. There is no *a priori* reasoning to suggest that any particular distribution is more appropriate (Greene 1993a, Harris 1993). The common approach is to try all three distributions and compare the results.

The results of the MLE are presented in Table 3. The model was run using all three distributions. The coefficients in the half normal and exponential models were almost identical. However, the μ/σ variable of the truncated distribution (which relates to the mean of the error distribution) was significantly different from zero, suggesting that a half-normal distribution (which assumes a zero mean) is an inappropriate assumption. Based on this, the model assuming a truncated distribution was adopted for the analysis of the individual boats' technical efficiency.

A number of parameter values of all three model were not significant. This is likely to be due to problems of multicollinearity[1]. As a result, the parameter values and hence any estimates of elasticities are unreliable. However, as the model is being used to estimate the maximum potential value of catch given input usage, and the relationships between the key variables are fairly constant[2], the predicted values are likely to still be reliable (Gujarati 1995). These can be compared to the actual value of catch of the individual boats to estimate the level of technical efficiency.

Most of the month and all of the year dummy variables were significant, indicating that variations in abundance has an impact on fishing revenues. The dummy variables representing the otter trawl métiers (U1.1 and U1.2) were not significant, indicating that fishing revenue in these métiers is not different to that in the inshore west beam trawl métier (U2.3), once differences in boat size and time fished have been taken into account. Most otter trawl activity occurs close inshore. As a result, the catch composition and abundance are likely to be closer to the inshore beam trawl operators than the offshore beam trawl operators.

[1] Pascoe and Robinson (1998) overcame similar problems when estimating the production function for the beam trawl fishery by using principal components.

[2] As much of the multicollinearity arises out of the squared and product terms, the relationship between these variables will be fairly constant.

Table 3 Stochastic Frontier models

	Distribution assumption								
	Truncated			Half normal			Exponential		
	Coefficient	T-statistic		Coefficient	T-statistic		Coefficient	T-statistic	
constant	-2.8919	-0.365		-4.3205	-0.653		-4.3209	-0.653	
lndeck	2.5539	0.769		3.4466	1.171		3.4474	1.171	
lnkw	-0.2298	-0.177		-0.3947	-0.270		-0.3951	-0.270	
lnhours	1.0036	9.218	**	0.8329	6.976	**	0.8326	6.974	**
$lndeck^2$	0.5709	1.010		0.4929	1.041		0.4927	1.040	
$lnkw^2$	0.5084	1.894		0.5754	2.015	*	0.5752	2.014	*
$lnhour^2$	0.0366	4.167	**	0.0425	4.293	**	0.0425	4.293	**
lndeck*lnkw	-1.1716	-2.052	*	-1.2463	-2.407	*	-1.2460	-2.405	*
lndeck*lnhour	-0.2096	-6.704	**	-0.1439	-4.288	**	-0.1439	-4.288	**
lnkw*lnhour	0.0946	2.943	**	0.0598	1.829		0.0598	1.830	
Month dummy variables									
February	-0.0223	-0.305		-0.0224	-0.281		-0.0224	-0.281	
March	-0.0275	-0.389		-0.0180	-0.231		-0.0180	-0.231	
April	-0.1042	-1.522		-0.1017	-1.360		-0.1017	-1.360	
May	-0.2338	-3.988	**	-0.2220	-3.605	**	-0.2220	-3.606	**
June	-0.1807	-3.058	**	-0.1676	-2.642	**	-0.1677	-2.642	**
July	-0.2127	-3.311	**	-0.2061	-3.095	**	-0.2061	-3.096	**
August	-0.1951	-2.456	*	-0.1892	-2.352	*	-0.1892	-2.351	*
September	-0.1266	-2.109	*	-0.1191	-1.902		-0.1191	-1.902	
October	-0.1297	-2.450	*	-0.1338	-2.405	*	-0.1338	-2.405	*
November	0.0247	0.373		0.0215	0.309		0.0215	0.309	
December	0.0245	0.400		0.0243	0.372		0.0242	0.372	
Year dummy variables									
1993	0.1338	4.114	**	0.1162	3.331	**	0.1162	3.330	**
1994	0.1490	5.212	**	0.1451	4.646	**	0.1451	4.646	**
1995	0.1773	3.058	**	0.1582	2.538	*	0.1582	2.538	*
Métier dummy variables									
U1.1	0.0132	0.206		0.1183	1.435		0.1182	1.434	
U1.2	-0.0303	-0.490		0.0917	1.248		0.0917	1.248	
U2.1	0.2117	6.273	**	0.2327	6.442	**	0.2327	6.442	**
U2.2	0.0624	2.122	*	0.0719	2.179	*	0.0720	2.179	*
μ/σ	0.8253	74.558	**						
σ^2_u/σ^2_v	3.7247	2.077	*	0.7087	2.052	*			
σ^2_v	0.2255	43.554	**	0.2401	42.133	**			
θ							0.7088	2.052	*
σ_v							0.2401	42.131	**
log likelihood	-1486.3			-1539.88			-1539.88		
σ^2_v	0.2255			0.2400			0.0576		
σ^2_u	0.8399			0.1701			1.9903		

Notes: ** significant at the 1 per cent level. * significant at the 5 per cent level.

The Battese and Coelli (1988) procedure was used to estimate the technical efficiency measures for each boat from the regression results. The distribution of technical efficiency in the sample examined is illustrated in figure 3.

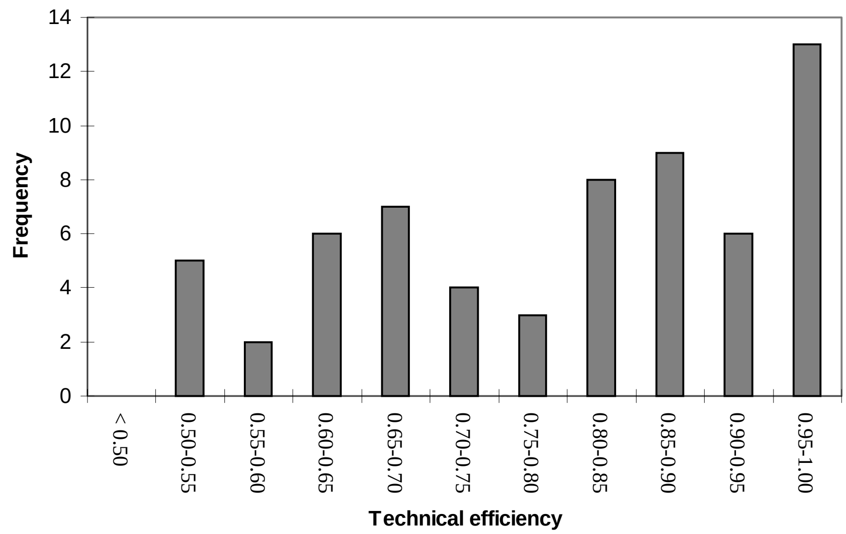


Figure 3 Distribution of technical efficiency in the demersal trawl fishery

From this figure it can be seen that there a considerable range of efficiency in the fishery. A small proportion of the sample (5 of the 63 boats) were operating with efficiency levels of around 50 per cent. That is, the value of their catch was only 50 per cent of the potential value given the level of inputs employed (e.g. boat size, engine power, hours fished). Conversely, 13 of the 63 boats were operating at levels of efficiency between 95 and 100 per cent.

Factors affecting technical efficiency

From the discussion of fishing powers, it is possible that most of the variation in technical efficiency is due to differences in skipper skill. However, not all factors that may affect the catch rate were included in the model. Hence, some of the variation may be due to factors other than skipper skill.

The key factors that were not included in the frontier model were the degree of specialisation, the age of the boat and the number of crew employed. Studies in other industries suggest that the greater the level of specialisation then the greater the level of technical efficiency (see for example Harris 1993). However, most of the boats in the sample operate using both beam and otter trawl. As these are different activities, non-specialist boats may be less efficient than the specialist boats.

There is no *a priori* reason to assume that age of the boat would affect the catch as the age itself represents the age of the hull only. Engines can be replaced and in most cases are newer than the hull (Pascoe, Robinson and Coglan 1997). Search technology (such as on-board navigation and sonar equipment) is regularly updated by all boats, a consequence of most of this equipment being hired or leased. Fishing gear is also replaced regularly, a consequence of the wear-and-tear it receives as a result of its use.

The number of crew were excluded from the regression model as it was highly correlated with boat size. There were also concerns about the direction of causality between crew size and catch rates. More crew may be required to handle the higher catch rate of larger boats rather than a contributor to the higher catch rates *per se*.

The correlation between these three variables and technical efficiency are given in table 4. Specialisation is defined as the proportion of total fishing time spent in the principal activity. From the table, none of the variables are highly correlated with the level of technical efficiency. However, the combination of these variables may explain part of the variation in technical efficiency. This was examined by regressing the variables against the technical efficiency measure. A log linear regression was run, the results of which are presented in table 5.

Table 4 Pearson correlation coefficients

	TE	age	crew	specialisation
TE	1			
Age	-0.2126	1		
Crew size	0.2742	0.4635	1	
Specialisation	0.1251	0.2507	0.5989	1

From table 5, it can be seen that age had an apparent significant negative effect on the level of technical efficiency while crew size had an apparent significant positive effect on efficiency. The degree of specialisation was not significant. In total, these variables explained about 14 per cent of the variation in technical efficiency, leaving 86 per cent of variation unexplained.

Table 5 Regression of boat characteristics against technical efficiency

	Coefficients	Standard Error	t Statistic
Intercept	-0.2777	0.1137	-2.442
age	-0.1039	0.0371	-2.799
crew size	0.2233	0.0691	3.230
specialisation	-0.1062	0.1632	-0.650
R Square	0.1861	Adjusted R Square	0.1447
F	4.4974	Observations	63

With regards to age, as noted above there is no *a priori* reason why the age of the boat would affect technical efficiency. It is possible that this result is spurious. Of the three variables examined, the only variable that might have been expected to have a significant effect was the degree of specialisation. However, this was both non-significant and negative, implying that technical efficiency, if anything, decreased with increasing specialisation. However, as this variable was correlated with crew size (Table 4) the wrong sign and lack of significance may be a result of multicollinearity in the model.

The relationship between specialisation and technical efficiency is also depicted in figure 4. Specialist boats are at either end of the figure, while non-specialised boats fall between this range. From the figure, it can be seen that there is no apparent trend, supporting the regression results that the degree of specialisation does not affect the level of technical efficiency.

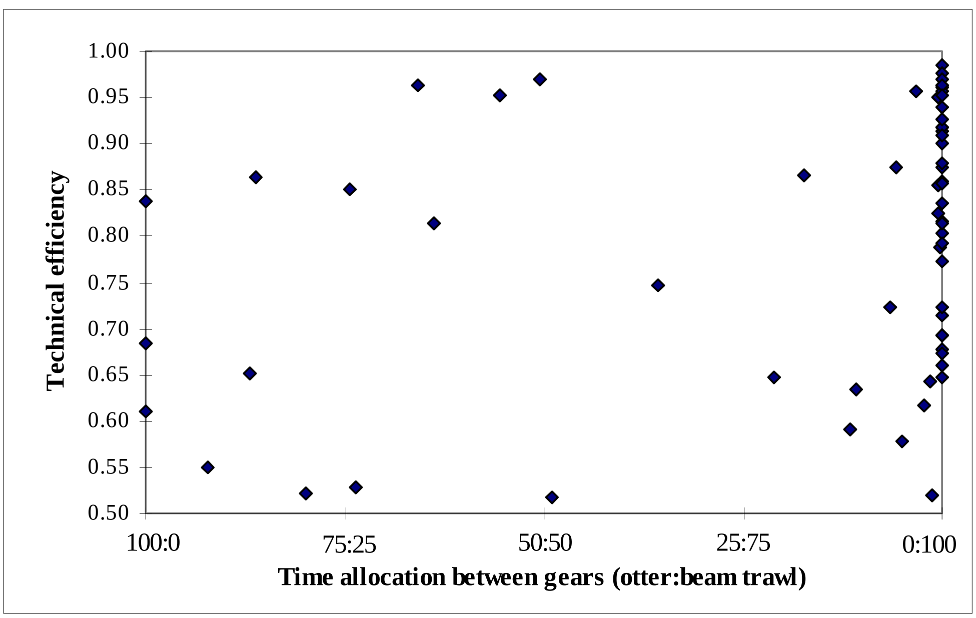


Figure 4 Technical efficiency and degree of specialisation

Discussion

The use of stochastic production frontier models may be more appropriate than traditional production functions in fisheries as they take into account differences in relative efficiency of individual boats. Traditional production functions can provide an indication of the relationship between inputs and catch of an average boat. However, for policy analysis it is preferable to know the potential level of production and the degree of inefficiency in a fishery particularly if input controls are to be used as the main management measure.

The estimation of levels of efficiency in fisheries has largely been limited to analyses of fishing powers. These are usually calculated on the basis of observed catch and effort and are averaged out over a number of fishing trips. Any random effects can therefore affect the average. However, stochastic production frontier models have the advantage that they can explicitly separate out the random effects from the boat specific effects. A further advantage of the stochastic production frontier model is that efficiency is measured relative to the best boat. In contrast, fishing powers only indicate relative efficiency compared to some pre-defined average boat.

In the case of the UK demersal trawl fishery, 70 per cent of the boats in the sample were below 90 per cent efficient, while 38 percent were below 75 per cent efficient. The least efficient boat was 51 per cent as efficient as the best boat.

Differences in efficiency can be explained by comparison of the efficiency measures with the characteristics of the boat. However, these measures only reflect difference in inputs not explicitly included in the regression model. Hence, factors such as boat size, engine power, amount of time fished, area fished and seasonal factors have already been taken into consideration in the analysis. Differences in efficiency therefore rely on factors other than these. These could include factors such as boat age, degree of specialisation, crew size and skipper skill. The first three of these factors only account for 14 per cent. While other authors have suggested that 'luck' may explain variation in performance between boats that can not be explained by physical characteristics of the boat, this element was removed as part of stochastic analysis. As a result it is reasonable to assume that the bulk of the variation is due to differences in skipper skill.

Differences in efficiency have consequences for policy aimed at effort reduction based on physical characteristics of the boats. For example, the decommissioning scheme in the UK focuses on the removal of vessel capacity units (VCUs). These are designed for each boat as a function of overall length, width and engine power[1]. However, where differences in efficiency are due to other factors removing boats units may not equate with an equivalent reduction in effort.

The relationship between the actual number of VCUs and effective VCUs in the sample is depicted in Figure 5. Effective VCUs are derived from the product of a boat's VCUs and its

[1] The actual calculation is given by VCU = length x width + 0.45 x engine power (kW).

respective efficiency. From this figure it can be seen that effective capacity diverges from actual capacity. Assuming that the least technical efficient boats are also the least profitable then these boats are likely to leave the fishery first. As a result the reduction in effective capacity will not be as great as the reduction in nominal capacity. For example, removing a boat with a TE score of 0.5 would imply that only half as many effective VCUs were being removed.

Given this, the effectiveness of the decommissioning scheme in terms of effort reduction will not be as great as it would be if all boats were of equal efficiency. Further, as most of the boats are operating at less than their full potential level of efficiency, effort in the fishery could still increase even though the number of units has decreased. Given that the main source of inefficiency may be skipper skill, technological development that can replace skill could result in a significant increase in efficiency and hence effective effort. An example of this that has already occurred in the fishery is the introduction of improved sonar equipment. This has increased the ability of skippers to find fish and has narrowed the efficiency differential between skippers[1].

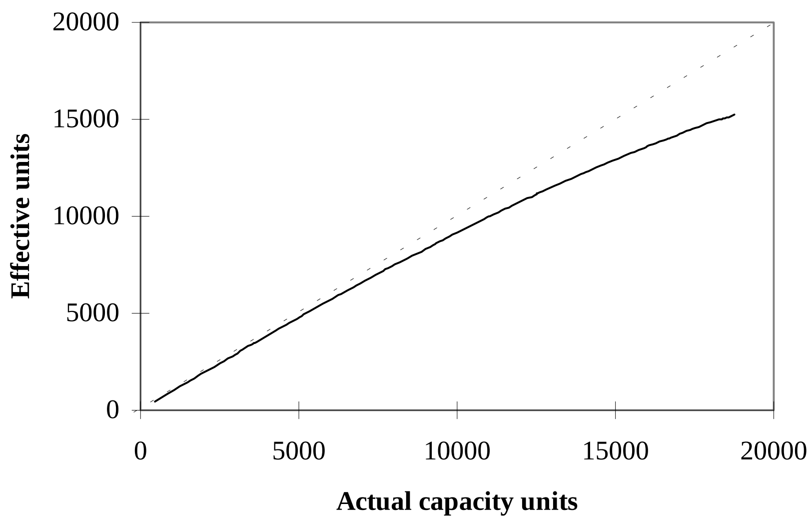


Figure 5 Actual units versus effective units

[1] Based on discussion with beamtrawl skippers in the fishery.

Conclusions

The use of stochastic production frontiers provides information on both the potential level of output given a set of inputs and the ability of the fleet to achieve this level of outputs. In the UK demersal trawl fishery operating in the English Channel about 70 per cent of the fleet are operating at less than 90 per cent efficiency whilst almost 40 per cent are operating at less than 75 per cent efficiency. Much of the difference in efficiency is due to unmeasurable inputs but most likely represents differences in skipper skill. As this is an uncontrollable input effort can still increase even in the presence of input controls and measures designed to reduce the level of capacity in the fishery.

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Fishing Effort Re-Allocation Under Unemployment Constraints

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Abstract

This paper[1] illustrates an improvement of the IREPA 'Moses' bio-economic model for the optimal management of fishing effort. A description of the model procedure for the optimal allocation of fishing effort and some results are reported. In order to assess the reallocation of labour units between areas and gears, an up-grading formulation of the concepts of inertia term and reconversion cost is introduced. Scope of this paper is the formulation of a linear programming problem that minimises the total reconversion cost of effort variations resulting from the optimisation analysis. Summary of the procedure is exposed, together with results applied to trawling and multipurpose fleet segments, combined. A brief discussion of results is also reported.

Introduction

The main features of Italian fisheries can be summarised as follows:

- Fishing areas are disseminated along the 8000-Km of national coast. Landing places are more than 800, launched by 15800 boats registered in 296 maritime offices.
- The fishery is multispecies and multigear. Multipurpose vessels are about 80% of the total of which 64% belongs to the small scale artisan fisheries segment (including long liners, trammel, small drifnets and gill nets). Vessels within class 0-10 GRT account for 78% of the total (amounting to about 12300) belongs to the 0-10 GRT class, while only 7% is over 50 GRT. Each gear competes with the others in catching more than 140 commercial species.
- Concentration of landings is very low. Considering that species are statistically recorded by 47 groups, for 23 species of them the ratio 'catches to total landings' is less than 1% and only for 11 the ratio falls between 1% and 2%. Gini coefficient for 1997 is around 0,54.

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[1] This paper is a revised version of a part of the more general study 'Innovative integrated bio-economic models for the management of multi-species and multi-gear fisheries', a research financed by EC, under project FAIR-CT95-0561.

- The active workforce is estimated in 40200 fishermen (1997 figure). Excluding pelagic species and some specific fishery (clams, juveniles, red shrimps), they are not able to target the species they intend to catch.
- Dependency of fisheries can be only stated at a local level (NUTS 3 level).
- The target of the activity of owners of Italian vessel is the income (which is almost essentially obtained through their work on board) more than profits maximization, i.e., the target is the gross value added maximization.

Considering all the above characteristics, the artisan management of the boats guarantee the necessary flexibility (linked to the diversification in fishing gears) to have stable volumes of catch and/or income. A consequence of these peculiarities is that the main tool to be employed by the public authority for the resources management should be based on the control of fishing effort and not on catch quotas. Therefore, following the implementation during 1982 of the licensing scheme, effort reallocation by gears and areas has been the main target for input control. Then, became important for the policy-makers to have a tool to be used for the choice of an optimal level of fishing effort.

Unfortunately, there is a lack of wide and reliable data on some fundamental aspects of fisheries, especially on migration of fleets, disaggregation of catch by gears, biological behaviour of species and their interactions. The Moses bio-economic model is specifically built to embody some of these aspects and therefore represents a management instrument that can be usefully employed by policy-makers.

2. The Moses model

The Moses model is a catch-effort model for multi-species and multi-gear fisheries, developed using catch and effort time series. It can be used for both simulation and optimisation analysis. In the former case, the model performs catch and effort data through the estimation of parameters for logistic and biological models. In the latter case, it provides the optimal distribution of fishing effort over areas and gears according to different scenarios (each combining economic objectives and biological and inertia constraints).

The Moses model is based on two sub-models. The first contemplate a catch-effort model that determines the optimal value of the parameters characterising the selected functional form (dynamic Schaefer, dynamic Fox, Deriso-Schnute). The second, attached to the first, consists in an economic model, which allows the determination of the optimal distribution of fishing effort offering the maximum economic result (maximum value added) compatible with biological and inertia constraint. A simple flow-Chart of the model is reported in figure 1.

In this paper, we focus on the economic sub-model. Following we shows briefly some results of its application to the Italian fisheries using the dynamic Schaefer model while Annex

1 depicts the optimisation procedure. Section 3 presents a fundamental improvement to the treatment of the inertia constraint and aims to take into consideration the cost of effort reconversion, connected to the reallocation of the fleet among areas and systems, as well as the possibility of hiring or firing labour units. Added to the other hypotheses, herein is used an indicator linked to unemployment data as a proxy of the opportunity cost of firing effort units. Section 4 is devoted to the exposition of the most relevant results and their discussion. Section 5 reports a summary of the study and Section 6 states briefly the future work.

Some results of its application to the Italian fisheries

Optimisation has been applied on a set of Italian fisheries [1] (year 1968-1992, 47 species, 10 areas), under a dynamic Schaefer model. Starting from the situation of the reference year (called Case A), three different scenarios have been defined (Table1), according to different weights to biological and inertia constraints. Case B is characterised by the absence of any biological constraint and a medium value of the inertia constraint (F=2). The solution then corresponds to the maximum value added, compatible with variations of fishing effort within twice the measured standard deviation for each area/fleet segment combination. Case C considers a medium biological constraint (set equal to 2) and the same inertia constraint as case B. Case D considers a severe biological constraint (set equal to 0.5) and the same inertia constraint as case B.

For each case, the optimisation problem has been solved starting from the reference effort distribution, obtained by setting unit values for the vector x.

Table 1 Description of the cases considered for the optimisation analysis

Case	Description	Maximum value of biological constraint for area (VBmax)	Weight factor for the inertia constraint (F)
A	Reference situation	not imposed	0 (maximum severity)
B	Maximum value added with medium inertia constraint	not imposed	2
C	Maximum value added with medium biological constraint and inertia constraint	2 (medium)	2
D	Maximum value added with severe biological constraint and medium inertia constraint	0.5 (severe)	2

[1] See IREPA (1993), pp. 62-74.

In table 2, for each case the results of value added, revenues and costs are reported together with the global value of the biological constraint.

Table 2 Optimisation analysis - Global results (economic figures in Billions Lit)

Case	Value added	Revenues	Costs	Biological violation
A	1516.4	2598.9	1082.4	16.8
B	2158.8	3500.1	1341.4	31.8
C	1928.9	2955.2	1026.3	15.5
D	1675.1	2447.0	771.9	06.0

Examining the results, some brief considerations can be drawn.

In cases B, C, D the value added always increases with respect to case A (reference situation). The best result is obtained in Case B, with gradual reduction when biological constraint becomes more binding, while the opposite trend is observed for the biological violation. This performance is due to the absence of any biological constraint. In fact, the total biological violation in Case B is almost twice as much the level of case A (but there is a relevant increase in revenues and a more limited growth in costs). In Case C, the total biological violation is slightly less than case A, but there is a considerable increase in the level of value added, since revenues are higher and costs are lower. Finally, Case D exhibits a more limited value added improvement (only 150 Billion It. Lira with respect to case A), due to a slight reduction in revenues and a good decrease in costs. In all the previous cases, the diminution of costs is linked to a better distribution of fishing effort among gear and areas, and sometimes also to a reduction of its level.

Of course, the model offers a high disaggregation of results. In fact, for each case we can have detailed indications on the distribution per area of revenues, costs, biological terms and fishing effort, so that one can take into account the local biological and effort situations[1]. The results of the optimisation analysis show that relevant improvements can be obtained by optimal management techniques by adopting realistic strategies for the reduction and redistribution of fishing effort, able to improve economic outcome and to avoid resource depauperation. These evaluations show the flexibility of the bio-economic model for the optimal allocation of fishing effort. It can suggest solutions maximising economic outcomes, but it can also propose management options, as Case C. In that case, both economic and biological results are improved, with realistic redistribution of fishing effort, with respect to the present state and more favourable conditions for stock conservation.

[1] For the result disaggregation, the reader can still refer to IREPA (1993).

3. Inertia constraint and reconversion cost: a new formulation

Inertia term has been introduced in order to limit excessive changes in effort distribution from the reference situation (corresponding to the actual distribution of effort) to the proposed optimal solutions. Within the model for the optimal management of fishing effort, some studies have been started to provide a more complete formulation of the inertia constraint[1]. They aim to a more realistic representation of the costs of the production reconversion linked to the transfer of the fleet among different areas and/or systems. From a theoretical point of view, this methodology should be able to take account of the costs linked to the production reconversion. In this way, it would be possible to consider the labour market and the sector constraints, since the adoption of multi-annual fishery policies (MAGP) or zones constraints necessarily require a basis of social consensus.

Unfortunately, a deeper analysis of previous applications on these aspects revealed that:

- positive and negative changes in fishing effort produce the same value of the inertia term in the model, although on the basis of an economic and social perspective they can not be considered as equivalent;
- this approach does not consider the cost transfers of fishing effort between different area/fleet segment combinations.

In order to overcome the cited limitations, the formulation of the reconversion costs has been investigated at a deeper extent and the subsequent terms are defined:

NK	number of 'activities' (area/fleet segment combinations) for which a reconversion or a transfer can be conjectured; the fictitious activity 'NOJOB' (index k=NK) is also included, in order to contemplate the relocation to the unemployment status or, on the contrary, the starting of new activities;
E*(k) k=1,NK-1	Reference distribution of fishing effort for the NK-1 area/fleet segment combinations;
E(k) k=1,NK-1	Proposed distribution of fishing effort for the NK-1 area/fleet segment combinations;
ΔE(k1,k2)	Transfer of fishing effort from the activity K1 to the activity K2; The index K1=NK points out the starting of new employment; The index K2=NK points out the emerging of new unemployment; It is also: ΔE(k,k)=0;
RC(k1,k2)	Unit reconversion costs per unit of effort, connected to the switching from the activity K1 to the activity K2.

[1] See also IREPA. Coccorese et al. (1997).

The total reconversion cost TRC is then given by the expression below:

$$TRC=\sum_{(k1=1,NK)} \sum_{(k2=1,NK)} \Delta E(k1,k2)\ RC(k1,k2)$$

Therefore, for each of the NK activities, the sum of the rows of the matrix ΔE represents the total effort moved from the K-th activity to the others:

$$\sum_{(K1=1,NK)} \Delta E(K,K1) \qquad K=1,NK$$

while the sum of each column characterises the effort relocated from other activities to the K-th activity:

$$\sum_{(K1=1,NK)} \Delta E(K1,K) \qquad K=1,NK$$

For K=NK, the above expressions show the total activation of new employment and the total transition to unemployment, respectively.

For the first NK-1 activities (except the fictitious NK-th activity NOJOB, then), the following equalities must hold:

$$\sum_{(K1=1,NK)} \Delta E(K1,K) - \sum_{(K2=1,NK)} \Delta E(K,K2) = E^*(K)-E(K) \qquad K=1,NK-1$$

The identification of the matrix of transfers ΔE, that minimises the total reconversion cost, subject to the constraints on the effort distribution (which come out from the model for the determination of the optimal management of fishing effort), can be done by means of the formulation and the solution of a linear programming problem [1].

[1] Actually, it is known that a typical field of application of the linear programming techniques is the determination of the best allocation of scarce resources over a given number of activities. Among the most important references on the argument, see DORFMAN et al. (1958), GALE (1960) and DANTZIG (1963). In this case, the model provides the optimal variation of the fishing effort (as obtained thanks to the optimisation model) for each area and system. In the outlined context, the linear programming could then be useful to establish how to redistribute the effort among areas and systems at the lowest cost. The ability of the linear programming in solving problems of optimal allocation of resources (in spite of the underlying restrictive hypotheses of linearity and divisibility) is also testified by the remarkable economic benefits gained by those firms which used it in a wide and substantial way (especially in the United States). The activity analysis, derived as an application of linear programming, can be considered one of the main foundations of the modern studies aiming to solve problems of optimal allocation of resources. As an example, see KOOPMANS (1951).

In general terms, the formulation of a linear programming problem suitable for our purposes can be done in the following way: the goal is the minimisation of the linear function z of the N independent variables x_j:

$$\min z = a_{01}x_1 + a_{02}x_2 + ... + a_{0N}x_N$$

subject to M linear constraints:

$$a_{K1}x_1 + a_{K2}x_2 + ... + a_{KN}x_N <=> b_K \geq 0 \qquad K=1,M$$

and to N further 'natural' constraints:

$$x_1 \geq 0 \quad x_2 \geq 0 \quad .... \quad x_N \geq 0$$

For the particular problem, the number of the N independent non-negative variables x is equal to the square of NK. These variables are linked to the terms of the matrix of transfers ΔE. The constraints can be divided into two groups.

The first is composed by M=NK-1 equality constraints, representing the relationships E*(K)-E(K) exposed above. From an economic point of view, each of the M constraints states that transferring units of fishing effort, from the considered area/system combination to another one or the opposite movement, must respect the result of the optimisation process for that particular area/system combination. For this reason their algebraic sum must be set equal to the difference E*(K)-E(K) [1].

The second group of constraints, whose number is also M=NK-1, has the following structure:

$$\sum_{(W=1,NK)} \Delta E(K,W) \leq E^*(K) \qquad W=1,NK-1$$

Such inequality constraints assert that each activity can not send to the other area/system combinations more effort units than its starting endowment. In this way, we rule out the possibility that the cost of the effort shifting between distant areas is artificially kept at a minimum level, thank to continuous transfers between contiguous areas (at least when these

[1] In fact, every coefficient a_{Kj} can assume only the values +1 or -1, in accordance with the possibility that the examined combination receives from or distributes to other area/system combinations a certain amount of effort. Of course, the value of the coefficient assumes the value 0 if there is no exchange between the combinations. This implies that each of the NK^2 columns of the coefficient matrix in the linear programming problem (matrix which is formed by the coefficients a_{Kj} of the left-hand variables in the M equality constraints), is an activity vector, since it indicates the requirement of units of effort (coming from another given area/system combination) necessary for a unitary increase of the level of fishing effort in the considered combination. The coefficient a_{0j} in the objective function, corresponding to the variable x_j and hence to the j-th activity vector of the matrix A, coincides with the cost of activation of the exchange between two given combinations.

transfers concern an amount of effort which is bigger than the reference value of any target area/system combination staying in an intermediate position of this 'chain').

In order to depict the structure of the problem for a simple case, if we consider two fishing areas (A1 and A2) and two fishing systems (S1 and S2), the possible area/system combinations are 4. Therefore it is NK=5, since we must compute also the fictitious activity NOJOB (NJ). It follows that the independent variables x_j are $NK^2 = 25$, while the constraints are $2*(NK-1) = 8$.

The problem is then:

$$\min TRC = \sum_{(k1=A1,A2,S1,S2,NJ)} \sum_{(k2= A1,A2,S1,S2,NJ)} x_{k1,k2}\, RC_{k1,k2}$$

subject to the following constraints:

$$x_{A1S2,A1S1} + x_{A2S1,A1S1} + x_{A2S2,A1S1} + x_{NJ,A1S1} - x_{A1S1,A1S2} - x_{A1S1,A2S1} - x_{A1S1,A2S2} - x_{A1S1,NJ} = \\ = E^*(A1S1)-E(A1S1)$$
$$x_{A1S1,A1S2} + x_{A2S1,A1S2} + x_{A2S2,A1S2} + x_{NJ,A1S2} - x_{A1S2,A1S1} - x_{A1S2,A2S1} - x_{A1S2,A2S2} - x_{A1S2,NJ} = \\ = E^*(A1S2)-E(A1S2)$$
$$x_{A1S1,A2S1} + x_{A1S2,A2S1} + x_{A2S2,A2S1} + x_{NJ,A2S1} - x_{A2S1,A1S1} - x_{A2S1,A1S2} - x_{A2S1,A2S2} - x_{A2S1,NJ} = \\ = E^*(A2S1)-E(A2S1)$$
$$x_{A1S1,A2S2} + x_{A1S2,A2S2} + x_{A2S1,A2S2} + x_{NJ,A2S2} - x_{A2S2,A1S1} - x_{A2S2,A1S2} - x_{A2S2,A2S1} - x_{A2S2,NJ} = \\ = E^*(A2S2)-E(A2S2)$$
$$x_{A1S1,A1S2} + x_{A1S1,A2S1} + x_{A1S1,A2S2} + x_{A1S1,NJ} \quad E^*(A1S1)$$
$$x_{A1S2,A1S1} + x_{A1S2,A2S1} + x_{A1S2,A2S2} + x_{A1S2,NJ} \quad E^*(A1S2)$$
$$x_{A2S1,A1S1} + x_{A2S1,A1S2} + x_{A2S1,A2S2} + x_{A2S1,NJ} \quad E^*(A2S1)$$
$$x_{A2S2,A1S1} + x_{A2S2,A1S2} + x_{A2S2,A2S1} + x_{A2S2,NJ} \quad E^*(A2S2)$$

$$x_{k1,k2} \geq 0 \quad k1=A1,A2,S1,S2,NJ \,;\, k2= A1,A2,S1,S2,NJ$$

The linear programming problem has been solved using the simplex method, based on the implementation of Kuenzi, Tzschach e Zehnder[1].

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[1] See PRESS et al. (1986). In the present stage of the research, the computational program is implemented in compiled Quick Basic. The memory space required by the actual structure of the algorithm applying the simplex method is in the order of $(NK)^3$. With the limits of memory imposed by the above programming language, to date, it is possible to solve problems characterised by a maximum number NK of area/fleet segment combinations equal to 20. The maximum number of all theoretically possible combinations is equal to 80 (10 areas times 8 systems).

4. Results and discussion

The developed methodology has been applied to the cases of effort reconversion over the ten Italian fishing areas for bottom trawlers and multipurpose vessels, starting from the results obtained with the optimisation analysis using the dynamic Schaefer model [1]. The effort distribution (i.e. Case A) has been assumed as reference distribution (E_{ref}), while the proposed distribution (E) [2] is the one coming from the maximisation of the value added with medium biological and inertia constraints (Case C) [3].

Different hypotheses have been considered according to various structures of the unit transfer costs. It is important to stress now that it has been always assumed that there is no cost for the activation of new effort units, while, with reference to the dismissal of effort, three different hypotheses have been formulated:

- H1) for all areas, the cost required by the transfer of a unit of effort to unemployment (NOJOB) activity is zero;
- H2) for all areas, the cost required by the transfer of a unit of effort to unemployment (NOJOB) activity is 10;
- H3) for each area, a relative dependence indicator has been computed as the percentage ratio between the number of fishermen and the total number of jobs in firms and other institutions in that area. This ratio has been then multiplied by an unemployment indicator for the same area[4]. The resulting value (called 'index of unemployment') has been lastly scaled, in such a way that the national average of all of them is 10 (for more details, see table 3). Therefore, here the cost of firing an effort unit is directly linked to the importance of the fishing activity in the considered area and to the general unemployment level. Furthermore, a comparison with the results obtained using the previous hypothesis is still possible given that the average cost on a national basis is equal to 10. The disaggregation is at a province level in order to take into account the coastal zones situation only.

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[1] The tables with the results of the optimisation problem here used can be found in IREPA (1993), pp. 71 and 73.

[2] It must be recalled that, in this application of the model, the fishing effort E_{tj} for the j-th system in year t has been computed as a function of GRT, of the engine power P (in kW) and of the yearly number of fishing hours H. The employed standardisation of fishing effort has been the following: $E_{tj} = (GRT \cdot P^{0.5} \cdot H)^{0.5}$. See IREPA (1993), p. 9.

[3] According to the results, for the trawler segment the proposed distribution suggests a slight global reduction of effort. In particular, global reduction results from a strong contraction in Sicilian area (A6S1), a little contraction in Sardinian (A5S1) and Ionic (A7S1), and a small increase of effort in the other areas. For the multipurpose gear, the maximisation of the value added recommends a consistent global decline of effort, to be carried out through a diminution in all areas, especially in Sicilian Sea (A6S8), with the exception of Sardinian (A5S8) and Lower Adriatic (A8S8).

[4] The unemployment indicator has been obtained by calculating the share of active resident population (aged from 15 to 64) which is not employed in firms or other similar institutions.

For simplicity, detailed results of the application of the linear programming algorithm to a single fishing technique will not herein reported [1]. Nevertheless a synthesis is reported in figure 2 and some results are considered in the conclusions.

Application of the linear programming algorithm to a couple of fishing techniques

As said before, the proposed approach can consider more than one fishing system. It is useful to evaluate the viability and opportunity of transfers of efforts units, not only among areas but also among gears. Here the linear programming algorithm will be applied to the reconversion of the effort of bottom trawler (S1) and multipurpose vessel (S8) combined, along the 10 Italian fishing areas.

The application still starting from the results given by the optimisation analysis, under the dynamic Schaefer model and considering for each system as initial and final effort distributions the case A (reference year) and the case C (proposed solutions) series, respectively. The choice of the mentioned fleet segments is not casual, since it allows evaluating the flows of vessels and workers between rather homogeneous systems, so a more 'realistic' solution. However, the different degrees of difficulty in transferring vessels and workforce among different fishing systems can be always introduced in this analysis through the mere variation of the shifting costs.

With regard to the results, it has been employed the same framework as described before. So that the structure of the unit costs of transfer has been gradually changed, but always keeping constant the cost of moving one effort unit from the trawler to the multipurpose, and vice versa. This cost has been set equal to 2 in each of the following simulations [2].

The first case analysed assumes a constant cost of transfer among areas equal to 1 and null costs for the activation and the dismissal of effort units. It is easy to check in this simulation that the solution proposed by the linear programming algorithm is the mere aggregation of the results obtained for the single areas. This means that no effort movement among fishing systems or areas is convenient, but the only movements take place from or to the NOJOB activity; therefore, the total reconversion cost is still zero.

The second case under study reflects the combination of a constant cost of transfer among areas (equal to 1), while the unit transfer cost of labour to NOJOB activity has been set equal to 10. Here the solution can be still regarded as the aggregation of the single results, except differences concerning the bottom trawler. In spite of these differences, the total reconversion cost is again the mere sum of the costs (7.8758+31.1152=38.9910). Therefore,

[1] Both the series and tables describing the numerical results of the optimisation analysis are reported in the original work 'Innovative Integrated Bio-Economic Models for the Management of Multi-species and Multi-gear Fisheries' (FAIR-CT95-0561).

[2] For details about effort movement among fishing systems and/or areas, as derived from the application to 'case one' to 'case seventh' herein reported, see again 'Innovative Integrated Bio-Economic Models for the Management of Multi-species and Multi-gear Fisheries' (FAIR-CT95-0561), IREPA (1977).

no effort movement among fishing systems is convenient, but only among areas within the same system.

A third case is characterised by the same assumptions as before. The cost of the movement of effort units among areas is still 1, but, when these units are sent to NOJOB, their dismissal implies a cost which is linked to the unemployment rate of the area they belong to. Now the total reconversion cost (26.0119) is smaller than the sum of the solution values of each fishing system (actually, we have that 4.2974+22.4042=26.7016). This is due to the effort redistribution, this time involving both the areas and the systems and means that the combined solution suggests increasing the dismissal of labour in the bottom trawler with respect to the other system.

A fourth case considers the additional hypothesis of an effort shifting cost among areas, which increases together with the distance. For simplicity, it is still assumed equal to the absolute value of the difference between the indexes of the examined areas. Here the proposed solution allows a lower cost than the sum of the values suggested for the single fishing systems (42.2416 vs. 12.9280+31.1152=44.0432) because of the effort redistribution among areas and systems.

The fifth case there is a linearly increasing cost of the movement of effort units among areas according to the distance, and a dismissal cost linked to the unemployment level of the area. The total reconversion cost is smaller than the sum of the single solution values (33.6053 vs. 10.4456+24.4540=34.8996).

The last two cases herein considered better reflect concrete 'political' options, at least for the Italian case.

The following scenarios common considers the existence of an up-grading cost of transferring unit of efforts according to the less or more difficulties in switching between fishing areas (costs equal to 1), between systems (costs equal to 2) and between contiguous fishing areas and systems (cost equal to 3). These measures of costs are correlated to mobility and technological constraints and states that it is more costly to propose or apply technical reconversion than geographic reallocation. The hypothesis behind is that costs for changing fishing area within the same gear (i.e., re-allocation) is less than to changing fishing gear in the same area (i.e., reconversion) and both are less expensive than changing fishing area and gear in neighbouring areas (i.e., re-allocation and reconversion).
Another common feature of the following scenarios is a limitation to effort movements within two contiguous fishing areas. The last imposed limitation overlaps social and cultural mobility constraints and was suggested by continuous local 'social strikes' when it really happened.

Difference between the two final cases herein considered is related to the cost of transferring units of effort to employment dismissal or firing labour units. The sixth case contemplates a standard cost equal to 10 while the seventh case considers a shadow cost linked to the unemployment level of the area. In other words, differences regard degrees of local dependency on fisheries. The latter is correlated to economic and social constraints and states that it is more costly to propose or apply permanent fleet withdrawals followed by fishermen unemployment than reallocation or reconversion. It imposes, also, that minimisation of reconversion costs takes into account the social cost of transferring surplus of unit labours to areas with a high level of local unemployment.

The sixth case states that the cost of transferring one unit of effort to other areas is linked to distances between them, to a constant cost of transferring to NOJOB activity and to effort movement limitation within two areas, as illustrated above. The computed cost of reconversion is equal to 42.2416, still lower than the sum of the solutions given for the single fishing systems (44.0432=12.9280+31.1152) because of the possibility of redistribute effort also among gears.

The proposed solution by the optimisation model is a combined trawl and multipurpose effort reduction of 3.5970 units (see, Figure 3). NOJOB figures in the linear programming model should be of the same amount. The movement of effort among systems within the same area always starts from multipurpose and arrives to trawler; it involves the following areas: Ligurian (0.081), Upper Tyrrhenium (0.166), Medium Adriatic (0.657), Upper Adriatic (0.407). There is also another migration to be mentioned: it concerns 0.007 effort units that move from the multipurpose system of the Medium Tyrrhenium to the trawler system of the Upper Tyrrhenium. The aggregate of all these labour units is obviously equal to the total amount of effort, which has been reconverted from multipurpose to trawler (1.318 units). 92% of the 3.5970 effort dismissal units is concentrated in the Sicilian Sea (A6) while the residual quota is distributed between the Lower Tyrrhenium (A4) and Ionic Seas (A7). NOJOB units is equal distributed between multipurpose and trawl vessels.

As said before, reconversion units are confined to switches from the multipurpose segment to the trawling ones (A1S8 to A1S1; A2S8 to A2S1; A3S8 to A2S1; A9S8 to A9S1and A10S8 to A10S1). Reallocation between areas is mostly related to each single fishing gear even if transfers between areas are more consistent for the trawler segment. The effort dismissal is bigger for bottom trawler and smaller for multipurpose vessels than the single cases, also keeping the same values (1.866 vs. 0.548 units and 1.731 vs. 3.049 units, respectively).

The last case derives from the application of the effort movement linked to their relative distances, their limitation within two areas and the linked to the unemployment level of the areas. Again it happens that the global cost of reconversion in this case is still lower than the sum of the solutions given for the single fishing systems (34.4295 vs. 11.3353+24.4540=35.7893). Moreover, with respect to the previous case, where no link with the unemployment level of the area is considered, the reconversion costs are significantly lower (34.4295 vs. 42.2416). This means that considering the degree of local dependence on fisheries, reconversion costs decrease with respect to ignoring it. Furthermore, adding a social and more realistic option as the limitation to effort movements within two contiguous areas determines only a marginal cost increase (34.4295 vs. 33.6053, see Table 2).

Again, the proposed solution by the optimisation model is a combined trawl and multipurpose effort reduction of 3.5970 units (see, Figure 4). Now, the effort dismissal for the multipurpose segment reaches 63% of the total units while the residual quota obviously refers to the bottom trawlers. Another important aspect is that the Sicilian Sea (A6) does not send to unemployment any effort unit. The initial surplus in the Sicilian Sea is totally confined to reallocation within two contiguous fishing areas and no switching between fishing gears subsists, that is, no technical change must occurs in Sicily. In this case, the effort dismissal concerns trawling in the Medium Tyrrhenium (A3S1) and Adriatic Seas (A9S1) and, multipurpose vessels operating in the Medium (A3S8) and Lower Tyrrhenium (A4S8) and, also, in the Medium Adriatic (A9S8). Switching between contiguous fishing areas with the same gear is a more consistent process than in the last case considered, that is, reallocation is the main framework of the minimisation of costs.

Technical reconversion to different gears relates to a minor units transfers like the movements of the multipurpose segment to trawling activities, confined inside the same area, excluding the passage of the multipurpose in the Upper Tyrrhenium to the trawl segment in the Ligurian Sea (A2S8 to A1S1) and the multipurpose activities in the Sardinian Sea to the trawler in the Medium Tyrrhenium (A5S8 to A3S1).

5. Summary of the study

A Linear Programming technique for the optimal re-allocation of fishing effort among areas and fleet segments has been proposed, which minimises total reconversion cost. This approach represents a significant improvement with respect to the previous methodology adopting 'inertia' constrains, embedded in the MOSES code.

This technique is able to take into account both technical costs, related to effort reconversion and migration, and social costs, mainly linked to the unemployment level of the area.

The technique has been applied on two sets of results obtained by the application of a bio-economic optimisation model to the Italian fisheries.

The total reconversion cost is always lower when considering the unemployment level of each area. In such cases the proposed solutions allow to select reconversion, which are less expensive from a social point of view.

When reconversion between different fleet segments is also allowed, a lower optimal reconversion cost can be achieved.

In most cases, the imposed limitation to effort movements within contiguous areas does not affect the total reconversion cost, but only the effort flows between areas and fleet segments.

The results allow to evidence cases when some constraints do not significantly influence the social cost: this information can guide the fishing managers to devote their attention to other factors affecting reconversion.

6. Future work

Further analysis will be carried out on the influence of model parameters, e.g., structure and level of unit costs. Improvements on code implementation are in progress, to substantially reduce computational time and enhance memory capability, in order to link this procedure with the optimisation process of the bio-economic model.

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Flow-Chart of the Model for Optimal Fishing Effort Allocation

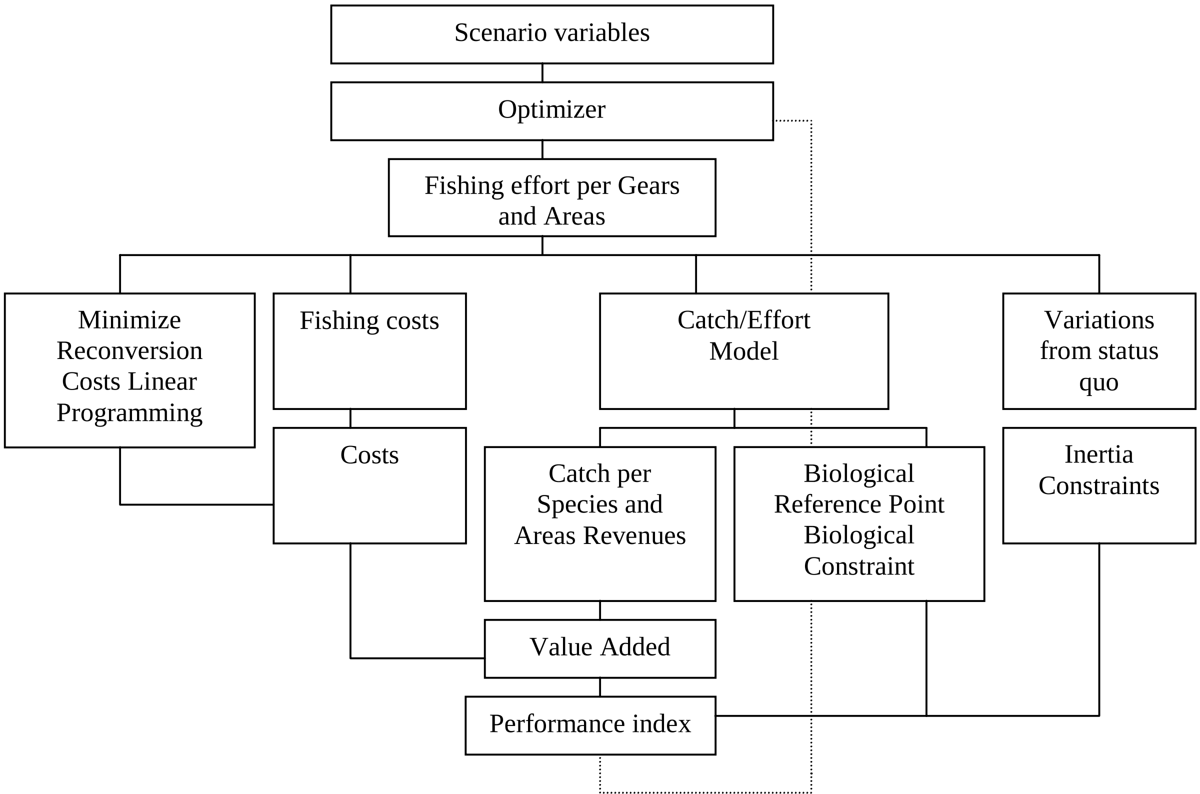


Figure 1 The Italian Model - MOSES

Costs of transferring one unit of effort to:					
Other areas	NOJOB activity	Limitation to effort movements	Bottom trawler	Multi-purpose vessels	Bottom trawler & multi-purpose vessels *
Constant (=1)	0	Absent	0	0	0
Constant (=1)	10	Absent	7.8758	31.1152	38.9910
Constant (=1)	Linked to the unemployment level of the area	Absent	4.2974	22.4042	26.0119
Linked to the distance	10	Absent	12.9280	31.1152	42.2416
Linked to the distance	Linked to the unemployment level of the area	Absent	10.4456	24.4540	33.6053
Linked to the distance	10	Within two contiguous areas	12.9280	31.1152	42.2416
	Linked to the unemployment level of the area	Within two contiguous areas	11.3353	24.4540	34.4295

* The cost of transferring a unit of effort from one system to the other is supposed equal to 2.

Figure 2 Minimization of Reconversion Costs via LP - Global Results

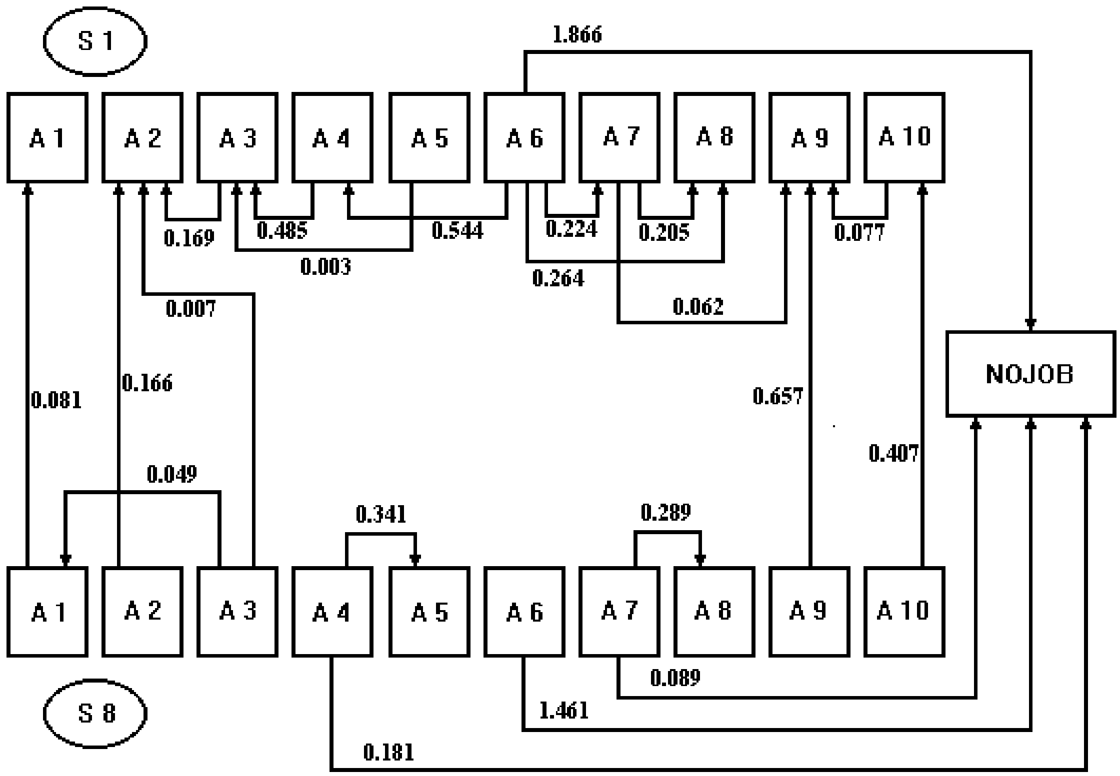
Table 3 Determination of the cost of unemployment for each fishing area

FISHING AREA	Total number of jobs in firms and other institutions	Number of fishermen	Unemployment indicator (%)	Relative dependence (%)	Index of unemployment	Cost of unemployment
Imperia	59332	367	59,30	0,62		
Savona	94396	583	50,89	0,62		
Genova	311291	763	52,03	0,25		
La Spezia	71865	355	53,65	0,49		
LIGURIAN	*536884*	*2068*	*52,99*	*0,39*	*20,41*	*5,94*
Massa C.	60236	49	56,17	0,08		
Lucca	131961	433	49,00	0,33		
Livorno	107479	2018	53,46	1,88		
Grosseto	61787	306	58,31	0,50		
UPPER TYRRHENIUM	*458694*	*2806*	*52,06*	*0,61*	*31,85*	*9,27*
Viterbo	69289	197	64,73	0,28		
Roma	1190374	913	55,13	0,08		
Latina	124753	970	62,86	0,78		
MEDIUM TYRRHENIUM	*1384416*	*2080*	*56,53*	*0,15*	*8,49*	*2,47*
Napoli	651739	2109	67,79	0,32		
Salerno	227817	1469	68,16	0,64		
Catanz.-Vibo-Crotone	132216	597	73,06	0,45		
Reggio Cal.	104700	1052	72,53	1,00		
LOWER TYRRHENIUM	*1499662*	*5227*	*69,52*	*0,35*	*24,23*	*7,06*
Sassari	118784	1270	62,39	1,07		
Cagliari	195321	1787	63,15	0,91		
SARDINIAN	*409509*	*3057*	*64,22*	*0,75*	*47,94*	*13,96*
Trapani	79372	3839	72,01	4,84		
Agrigento	78865	1730	75,08	2,19		
Siracusa	82255	2283	69,21	2,78		
Catania	213958	1099	68,92	0,51		
Messina	153419	1916	64,31	1,25		
Palermo	255884	2381	68,56	0,93		
SICILIAN	*974769*	*13248*	*69,32*	*1,36*	*94,21*	*27,43*
Catanz.-Vibo-Crotone	132216	1145	73,06	0,87		
Taranto	130084	1153	67,24	0,89		
Lecce	167041	1207	69,16	0,72		
IONIC	*622263*	*3505*	*69,86*	*0,56*	*39,35*	*11,46*

Table 3 continue

Brindisi	79350	579	71,36	0,73		
Bari	375877	2368	63,53	0,63		
Foggia	133686	1771	71,52	1,32		
LOWER ADRIATIC	*755954*	*4718*	*67,40*	*0,62*	*42,06*	*12,25*
Pescara	90189	2102	53,80	2,33		
Ascoli P.	131750	1058	46,22	0,80		
Ancona	165785	2144	44,21	1,29		
Forlì-Rimini	223999	746	46,84	0,33		
MEDIUM ADRIATIC	*1103460*	*6050*	*45,18*	*0,55*	*24,77*	*7,21*
Ravenna	130257	1211	46,42	0,93		
Rovigo	82599	1630	52,88	1,97		
Venezia	302971	1450	47,73	0,48		
Gorizia	51667	1057	45,90	2,05		
Trieste	96067	348	46,94	0,36		
UPPER ADRIATIC	*971518*	*5696*	*48,49*	*0,59*	*28,43*	*8,28*
ITALY	*8717129*	*48455*	*61,78*	*0,56*	*34,34*	*10,00*

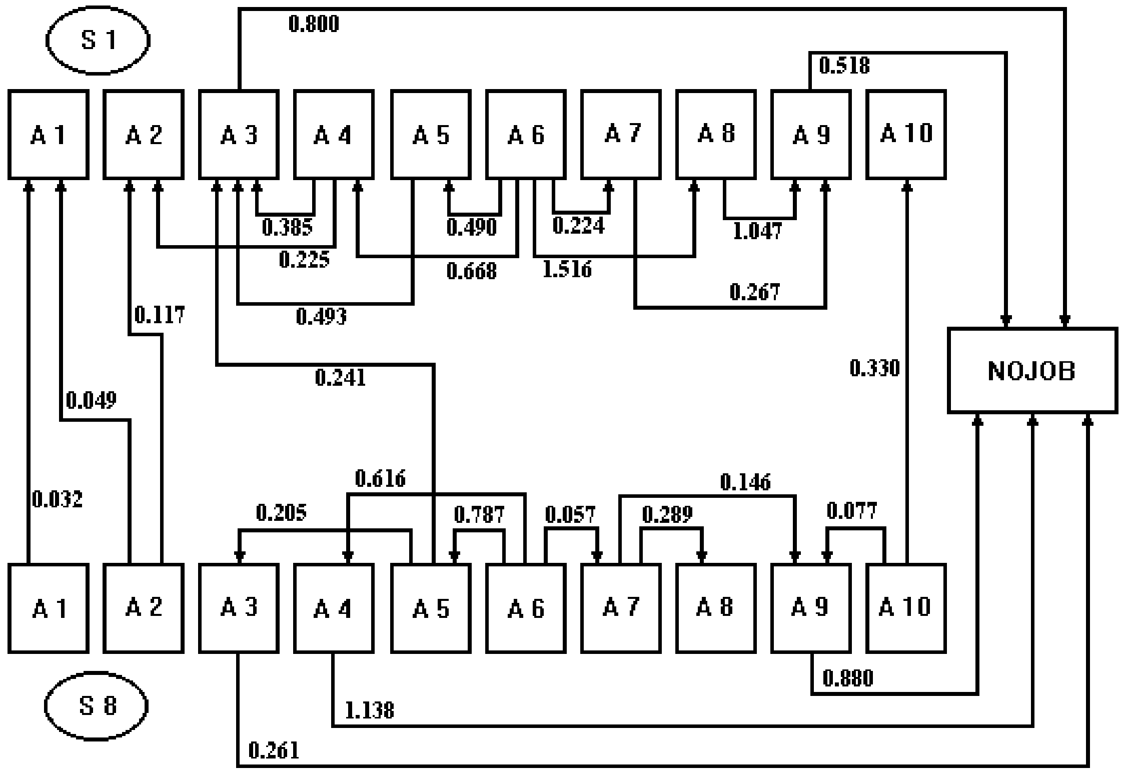
Source: Istat (1991 figures)



- Unit costs of effort transfer to other areas = linked to the distance
- Unit costs of effort transfer to unemployment = 10
- Limitations to effort movements = within two contiguous areas

Total reconversion cost = 42.2416

Figure 3 Results for bottom trawler & multi-purpose vessels



- Unit costs of effort transfer to other areas = linked to the distance
- Unit costs of effort transfer to unemployment = linked to the unemployment level
- Limitation to effort movements = within two contiguous areas

Total reconversion cost = 34.4295

Figure 4 Results for bottom trawler & multi-purpose vessels

Annex 1 Analytical features of the economic model

In order to achieve the optimal distribution of fishing effort, the Moses bio-economic model employs a non-linear optimisation procedure. The objective is the maximisation of the economic result, particularly the value added[1], under biological and inertia constraints. Biological constraint is introduced to avoid overfishing and biomass depletion while inertia constraint allows to selecting the optimal solution among realistic effort redistribution, which are identified within a given range of variation around the actual value of the effort.

For each catch-effort equation, the biological term VB_i has been defined as follows:

$$\begin{cases} VB_i = E_i - E_{m,i} & \text{if} \quad E_i > E_{m,i} \\ VB_i = 0 & \text{if} \quad E_i \le E_{m,i} \end{cases}$$

Here $E_{m,i}$ represents the effort corresponding to maximum catch in biological equilibrium conditions, that is the maximum sustainable yield (MSY). This value changes according to the selected catch-effort model.

For each area, a global biological term VB is computed as the ratio of terms VB_i for each species and total fishing effort in the area:

$$VB = \frac{\sum_{i=1}^{NSP} VB_i}{\sum_{i=1}^{NFS} E_i}.$$

This index can be interpreted as the fraction of the total effort exceeding the conditions corresponding to maximum catch for each species.

The differences between the proposed solutions and the actual ones have been taken into account thank to the formulation of an inertia constraint VI_i for each fishing system:

$$\begin{cases} VI_i = \left|E_i - E_i^*\right| - \Delta E_i & \text{if} \quad \left|E_i - E_i^*\right| > \Delta E_i \\ VI_i = 0 & \text{if} \quad \left|E_i - E_i^*\right| \le \Delta E_i \end{cases}$$

Here ΔE_i represents the maximum allowed variation around the reference value for the effort E_i^*, evaluated by the following relationship: $\Delta E_i = SD(E_i)F$. The value ΔE_i is then proportional to the standard deviation of the i-th fishing effort in the observed period in the given area. The factor F can be varied according to the scenarios considered in the

[1] The choice of the maximisation of the value added is widely discussed in IREPA.Coccorese *et al.* (1997).

optimisation analysis and therefore to the proposed management objectives. This procedure allows taking into account the 'elasticity' manifested by each segment of fleet during the previous period, for each area and fishing system. It is related to the micro-economic reactivity in the fisheries and/or to technological changes.

For each area, a global term VI is then computed as: $VI = \sum_{i=1}^{NFS} VI_i$. By the inertia term, it is possible to limit the variations with respect to the present effort distribution, selecting the distribution that, with equivalent economic and biological results, requires less re-conversion effort or cost.

The optimal fishing effort distribution in a given area corresponds to the maximum economic outcome (the value added) satisfying possible biological and inertia constraint:

$$\begin{aligned} &\max_x VA(x) \\ \text{s.t.}\quad & VB(x) < VB_{max} \\ & VI(x) = 0 \end{aligned}$$

where x represents a vector linked to the effort distribution of the reference year.

This problem is solved as a non-linear constrained minimisation problem employing the Augmented Lagrangian approach and Quasi-Newton techniques[1]. The above optimisation algorithm has been applied on a set of data of Italian fisheries[2] (years 1968-1992, 47 species, 10 areas), under a dynamic Schaefer model.

The Data Used

Catch-Effort Models:

- Catch time series per 47 species and 10 fishing areas (yearly data, 1968-92);
- Fishing Effort time series per 8 fleet segments and 10 fishing areas (yearly data, 1968-92);
- Specification of fleet segments concurring to the catch of each species (Technical Matrix);
- Recruitment age by species.

Data related to catch time series is the official ISTAT data adjusted by IREPA estimations. Fishing effort time series is based on official annual figures on GRT and Horse

Power, integrated with Irepa estimates of hours for fishing by fleet segments and fishing

[1] See GILL *et al.* (1981). The complete description of the economic model as well as the details of the optimisation procedure can be found in IREPA (1993).
[2] See IREPA (1993), pp. 62-74.

areas. Fishing effort used in the Moses model are standardised units. The technical matrix is a reduced form (47 per 8) of a general table relating 520 species and 42 fishing gears. Several biologist colleagues friendly stated recruitment age by 47 species.

Optimisation model:

- Unit fishing costs per 8 fleet segments and 10 fishing areas (reference year 1992);
- Prices for 47 species by 10 fishing areas (reference year 1992).

Unit fishing costs used into models are currently recorded by IREPA since 1983. Input data is cost/effort, were costs includes fix and variable costs but excludes labour costs and/or crew share, meaning that costs are equivalent to 'intermediary consumption's'.

The 10 fishing areas

Ligurian Sea, Upper Thyrrenium Sea, Medium Thyrrenium Sea, Lower Thyrrenium Sea, Sardinian Sea, Sicilian Sea, Ionic Sea, Lower Adriatic Sea, Medium Adriatic Sea and Upper Adriatic Sea.

The 8 fishing systems (fleet segments)

Bottom Trawlers, Pelagic Mid-water Trawlers, Purse-seiners, Long-Liners, Gillnets, Dredges, Other gears, Multiple purpose vessels.

How far are the French markets of seafood products integrated?

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Abstract

After the French market crisis in the early 1990s, the fish auction markets have responded differently according to the coastlines (English Channel, Atlantic ocean, Mediterranean sea). Therefore, the issue of market integration in France can be adressed.

Starting with average ex-vessel monthly prices observed between 1989 and 1997, a multivariate analysis is undertaken, crossing the price data by auction market, by month and year, and by species, followed by a time series econometric approach. The main objective is to stress the correlations between species with regard to price series in order to establish the relevant area of markets, both sectorally (degree of substitution between species) and regionally (inter-related auction markets).

To some extent, it can emphasize some breaks within the trend of the time series. Beyond these results, this approach attempts to show the dominant sources of price variability between the auction markets, the long run trends, the seasonal pattern or the coastline effect.

General introduction

During the 90s, the French fishing sector suffered from an important crisis, particularly affecting the 1993 and 1994 winters. That crisis was characterized by a noticeable drop in the turnover achieved. The measures taken by C. Josselin and J. Puech in 1993 and those by J. Puech and P. Vasseur in 1994-95 made it possible to both recoup this drop in equipment turnover and to limit the resulting social crisis, taking particularly into account the 'share' payment system applied in this field. The landings fluctuation analysis shows a certain continuity of supplies thus suggesting that the drop in turnover is generated by the increasing selling prices.

In France, there is a high diversity and heterogeneity of the fishing industry : number of ports scattered along the coastline, number of species produced and consumed, many types of fishing gears and fleets.

However, the market crisis in France (in February 1993 and February 1994) appeared to have affected the whole fishing industry. The objective of the research is to address this question: is this hypothesis true or not? Do some particular ports have been more affected than others ? What would be the reasons behind such a result? In other words, how well are the different French markets regionally integrated?

The regional aspect is the main objective of the current research because a sectoral integration would go far beyond the scope of this paper: i.e. between fish markets and meat markets, between the types of processing (fresh, frozen, salted, canned). This question does not mean also that the French market is only integrated inside the national boundaries because it might be integrated at the international level. Nonetheless these matters, we shall stick to the previous question.

Most of the economists now deal with the issue of market integration with time series analysis of prices (Asche & al. 1997). Some of the papers are using a cluster analysis in order to select the species on which the cointegration techniques will be applied (Jaffry & alii 1996). In these papers, the estimation of substitution between species is made possible by using time series based on national aggregated data.

In this paper, since we address the issue of regional integration between fish markets, we shall consider monthly average prices by species and by auction market over a period of time. Such a choice implies some missing values because some of the transactions (which is the basic unit in the analysis) are seasonal, or only related to some ports, or both of them. Since we intend to take into account the dynamics of behaviours, we shall use an approach in which the reference to time is preserved, as shown in the next section.

Methodology and data

The field covered by this paper concerns about fourteen ports over the period January 1989 to December 1997. If a certain number of informations exist about fish prices, they are often fragmentary, rough or too much aggregate and are not adequate to supply homogeneous time series which are necessary to measure precisely a complete set of variations over a long time.
This kind of data being unavailable at this time, it is necessary to build, in a first step, monthly price series to measure the volatility, species by species, and for a given number of fish auctions.

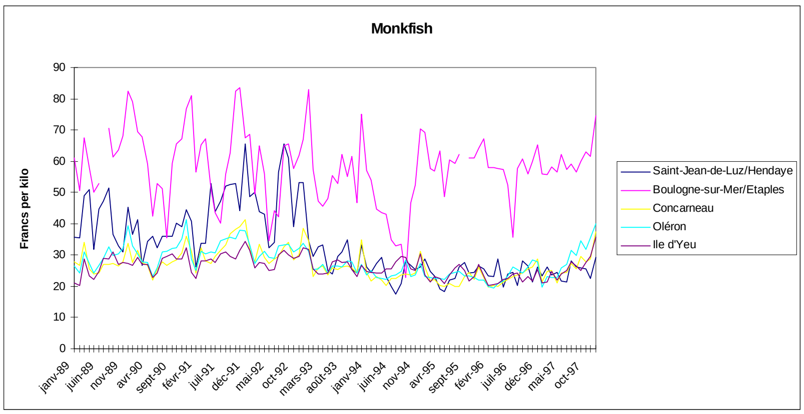
The source data used to calculate average monthly price series were available via the Centre Administratif des Affaires Maritimes (CAAM) established at Saint-Malo. The data files record every deal (port, date, species, price and weight) auction by auction and day by day. The data are related to the very first step of the sale, i.e. sale by auction.

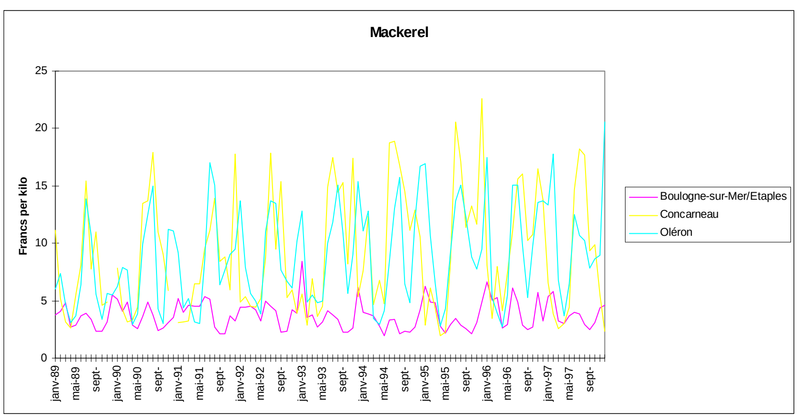
1. Data processing

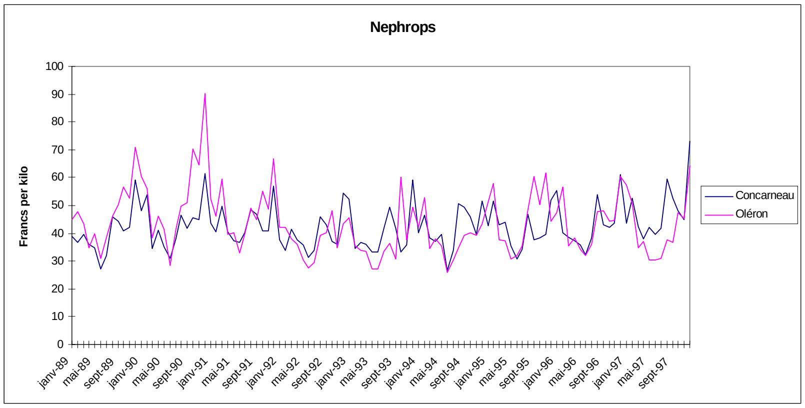
a A monthly price series processing method

From the daily raw data, it is possible to sum by port, by species and by month the total weight of the landings and the total expenditure of the corresponding deals. By a simple division, we can compute an average monthly price by species and by auction. Nevertheless, beyond this elementary scheme, some filters were applied to improve the results:

- elimination of null price or null weight when reading the raw source data records.
- elimination of every deal generating an average monthly price greater than 250 F per kilo (in order to withdraw potential errors) or unsignificant records.
- minimal number of records (5) to compute a representative average monthly price.







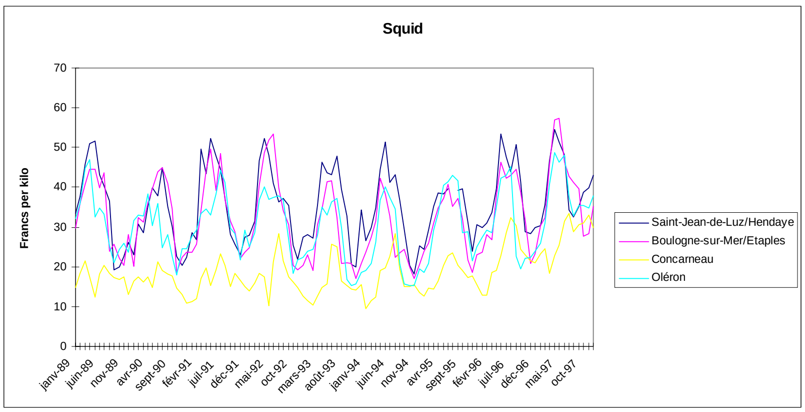


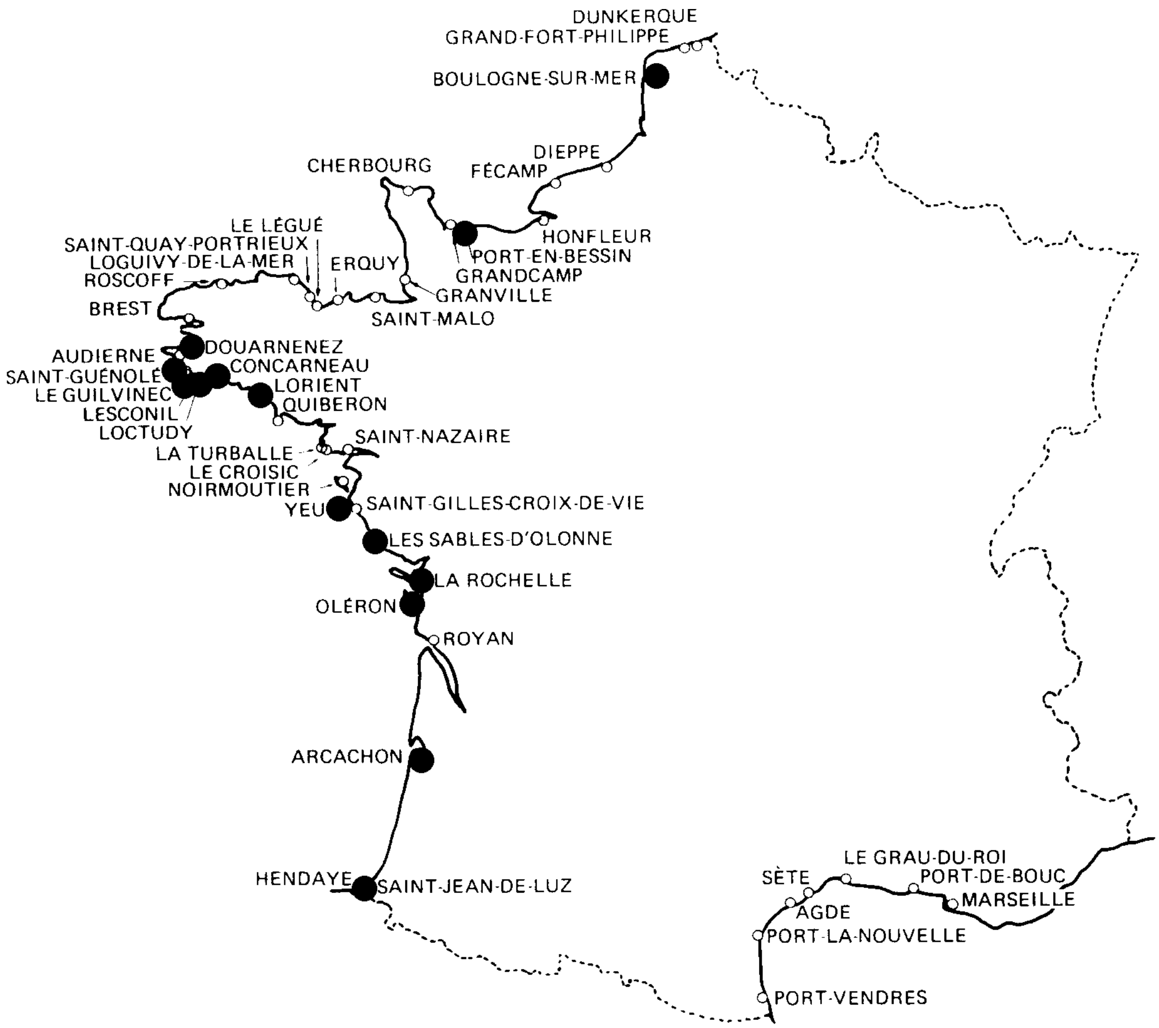
Figure 1 Four exemples of average monthly price by species

b Ports selection

The number of fish auctions appearing in the source data is 53. Furthermore, this number is fluctuating over the period 1989-1997. However, only 42/45 auctions are regularly and continuously in activity. The choice in the number of ports is based on the following five criterions:

- a value classification in the beginning of the period (1989) restricted to the first third, i.e. about fifteen ports.
- elimination of a port with a local specific activity which is not present on the whole french seashore: La Turballe or Saint-Gilles-Croix-de-Vie, two pelagic ports.
- elimination of a port for which average monthly price series were quite uncomplete : Dieppe.
- the amalgamation of ports such as Saint-Jean-de-Luz and Hendaye is explained by historical and geographical reasons.

- Arcachon has been incorporated for evident geographical reasons.



Map 1 Localization of the selected french ports

Finally, the 14 ports selected are:

1	Boulogne-sur-Mer/Etaples	8	La Rochelle
2	Concarneau	9	Douarnenez
3	Lorient	10	Port-en-Bessin/Honfleur
4	Le Guilvinec	11	Oléron
5	Loctudy	12	Saint-Jean-de-Luz/Hendaye
6	Les Sables-d'Olonne	13	Ile d'Yeu
7	Saint-Guénolé	14	Arcachon

c Species selection

From the 290 species registered in the CAAM nomenclature and the 192 ones really landed in the french auctions, 10 species have been selected. This choice is based on the following three criterions:

- a value classification (above one million francs on the period 1989-1997).
- the presence of the species in all the ports selected above: scallops, caught essentially in the Baie de Saint-Brieuc, is excluded; anchovy (close from the one million francs threshold), a pelagic species only caught by some harbor flotillas is rejected and substituted by mackerel, in spite of a smaller landings value but caught everywhere.
- hake is one of the five main species. Today, if there is no confusion to be afraid of in the records, we must be very careful about the term because in France, we can count at least 26 different regional names. Consequently, to avoid any confusion, we prefer to exclude hake from the statistical analysis.

Finally, the 10 species selected are:

1	Sole	6	Bass
2	Nephrops (Norway Lobster)	7	Saithe (Pollock)
3	Monkfish	8	Cuttle-fish
4	Cod	9	Squid
5	Whiting	10	Mackerel

At last, from all these criterions stated above, for each species, and for each port, we can now compute average monthly price series from January 1989 to December 1997. The resulting 15120 observations (14 ports*10 species*9 years*12 months) can be classified in a table:

- by columns, the variables (the species);
- by lines, the individuals (a synthetic value combining ports-months-years).

2. A typology of individuals by a hierarchical classification

Because of the non-price cells in the table crossing the species and the individuals (ports-months-years), a multiple correspondance analysis (MCA) has been preferred to a principal component analysis (PCA). The latter deals with continuous data whereas the former uses categorical data. Consequently, a first classification has been undertaken with prices, dividing each continuous variable (i.e. the price of a species) into 5 classes: a non-price (1), a low price (2), a medium-low price (3), a medium-high price (4), and a high price (5). The MCA gave the following results along the first two axis :

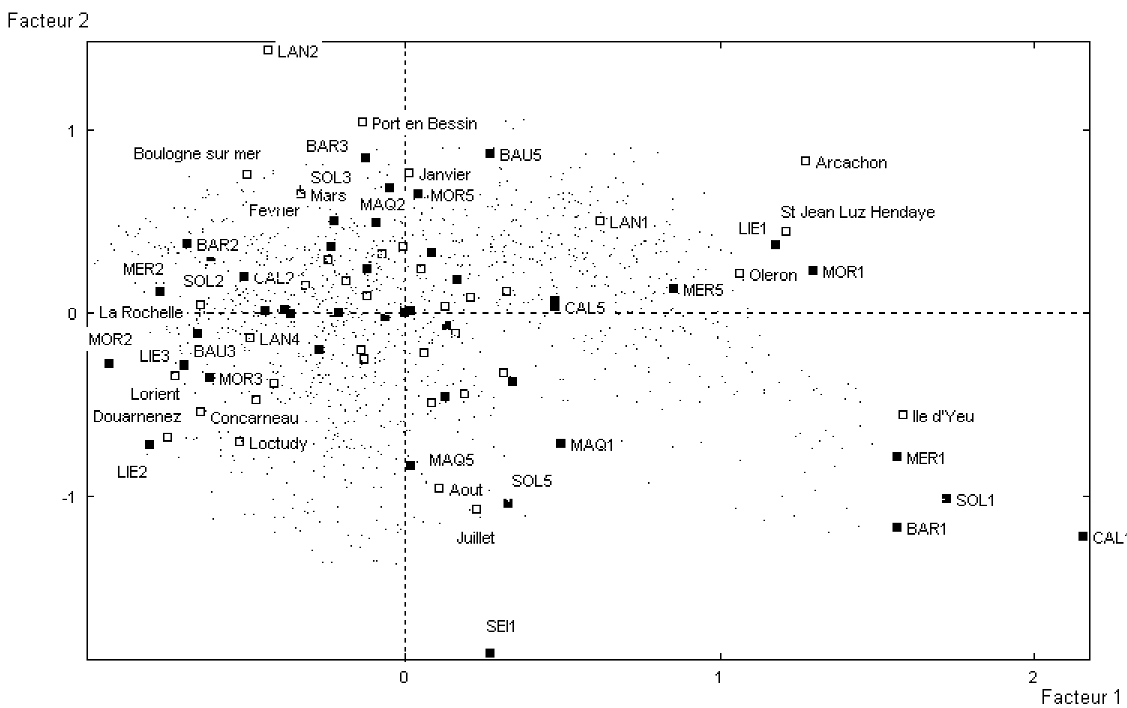


Figure 2 Factorial map of the MCA on fish market prices

Map Code	Species	Map Code	Species
SOL	Sole	BAR	Bass
LAN	Nephrops (Norway Lobster)	LIE	Saithe (Pollock)
BAU	Monkfish	SEI	Cuttle-fish
MOR	Cod	CAL	Squid
MER	Whiting	MAQ	Mackerel

Map Code Number	Price Signification
1	Non price
2	Low price
3	Medium low price
4	Medium high price
5	High price

The species-variables have been included as active variables and three other variables (kind of dummy variables, respectively for the port, the month and the year) have been inserted as additional ones in order to check which effect resulted in the highest variability of the standard deviations between the prices. As a result, a first analysis of the active variables may determine some relationship between the prices. The map must be read as follows : the closer the categories on the map (e.g. SOL1 for sole non-price and BAR1 for bass non-price), the higher the correlation. In other words, the two categories are represented with the same individuals. For instance, some species might fetch high values (and/or low) for the same individuals, hence producing a kind of correlation between them.

On the factorial map, most of the non-price categories are located in the same area, showing a proximity of the same individuals. The question is which dimension of the panel data set gives such a result. Is the non-price proximity due to a regional effect, a seasonal effect or a year effect? A regional effect would mean that the fishermen working in some of the 14 ports do and do not land the same species altogether (e.g. saithe for LIE1 and cod for MOR1). A seasonal effect would imply a non-price for the same months of the year (say the summer months for instance). The year effect would occur if a species had stopped to be landed by all the ports from a certain year. The projection of the additional variables gives some insight to this question.

Along factor 1, the right-hand side is clearly determined by the south-western ports (Ile d'Yeu, Oléron, Arcachon) and the left-hand side concerns the western ports (the ports of brittany and La Rochelle). The northern ports like Boulogne-sur-Mer and Port-en-Bessin are rather stuck-in-the-middle. Including nephrops in the active variables would tend to separate even more apparently the breton ports away from the others. A typology based on that variability (and Eigen values) is then set up. The automatical criterion is to maximize the inter-group variability and to minimize it inside the groups, in order to gather the closer individuals and to make sure that the groups are as homogeneous as possible. Such a classification was given by the following classification tree :

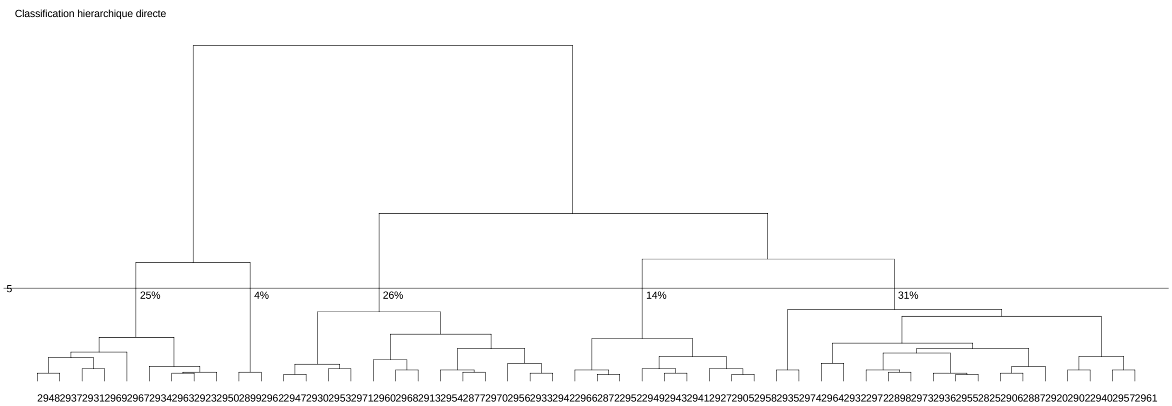


Figure 2 Classification tree and partition in 5 categories

The line shows the cutting of the tree into five groups and the percentages give the number of individuals in each group. The analysis also gives the main characteristics of each group on the basis of test-values, like for the tests of null hypothesis. Consequently, the most important categories attached to each group because it is over or under-represented in the group are emphasized. The description of these main categories is presented in the following table.

Categorie	Ports	Species			Features
		Non produced	Under-valued	Over-valued	
1	South western ports	Nephrops Saithe Cod		Cuttle-fish Squid	All months
2	Ile d'Yeu	Nephrops Squid		Whiting	
3	All ports			Cod	Years 1990-1991-1992 Winter
4	Western ports	Cuttle-fish		Sole	Summer
5	North western ports		Bass Sole	Saithe	Years 1993-1994 Years 1995-1996 Spring

This typology shows a double classification:

- first, a regional dimension with five zones clearly defined.
- secondly, a double temporal dimension by years and by seasons. The seasons are reflecting a seasonnality effect.

Concluding remarks

These conclusions confirm some published results: this variety of cases was illustrated through the Comité Interministériel de Restructuration de la pêche Artisanale (CIRPA) and by the reports drawn up by the Official Henaff-Mettling. These documents about the financial situation of the artisanal fishermen and PO clearly reveals that the crisis has been particularly strong for:

- deep sea whitefish catches (cod, whiting, saithe and herring).
- northern part of the Atlantic coast (french departments : Finistère, Morbihan, Loire-Atlantique and Charente-Maritime). However, mediterranean and northern flotillas seem to be less affected.
- trawling, especially pelagic trawlers rather than deep sea trawlers.
- ports not specialized in high value species and not promoting quality.
- 12-25 m ships (coastal vessels under 12 m in length are globally less underprivileged)

Finally, some evidence has been brought out of the national integration of fish market. However, two sets of questions may be asked:

- First, demonstrate this level of integration with time series econometric techniques that would take into account this regional and seasonal variability.
- Secondly, two hypotheses can be put forward to be further tested about the factors of integration for the french fish market:
    - what is the specific part of international markets on the integration of domestic prices?
    - what will be the part of computer science techniques on the uniformization of fish prices?

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The biological and economic impacts of discarding in the U.K. (East coast) Crangon crangon fishery

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Abstract

This paper outlines an approach to analysing and modelling discard data so that the estimated numbers of fish discarded within a particular fishery, could be placed in a quantifiable economic and biological perspective. The U.K. (East coast) *Crangon crangon* fishery has been studied extensively over a number of years through various research projects awarded to the University of Lincolnshire and Humberside. A large database relating to the discarding of commercial species of juvenile of fish that occurs within this fishery has been assimilated and subsequently 'modelled', in order to ascertain the commercial importance of this particular phenomenon. The economic and biological benefits of introducing the use of discard reducing, more selective fishing gears (veil nets) into this fishery are detailed.

Key Words: Discards, *Crangon crangon*, economic, impact, selective gears.

1. Introduction

The biological and economic impacts detailed in this paper are based on analyses of data gathered during the University of Lincolnshire and Humberside's research activities into Crangon related discarding during the period of 1993 to 1997. The U.K. (East coast) brown shrimp *(Crangon crangon*) fishery is recognised as a fishery which discards potentially significant numbers of juvenile commercial and non commercial fish as part of its normal current fishing operations (Andrew & Pepperel, 1992)(Graham, 1997)(Van Marlen et al, 1997). Discarding within this fishery occurs primarily due to the small mesh size of gears used (20mm inside / full stretched mesh) and the fact that the Crangon fishing grounds are often nursery areas for juvenile species of commercial and non commercial fish (Tiews, 1978). These juvenile fish by-catches are subsequently discarded overboard during the deck sorting of the catch but generally suffer high mortality rates due to the capture, sorting and deck handling processes (Bergahn et al., 1992). Quantitative estimates of this discarding have been made using data from a large number of sea trials performed during 1993-1996. The significance of this discarding has been examined, with resultant estimates made of the impacts, in terms of potential lost landings and associated market values. This work also details the predicted potential benefits (both economic and biological) that would result, if this fleet were to reduce current discarding levels by using more selective fishing gears.

2. Study Fishery - The U.K.(East coast) Crangon fishing fleet

The U.K (East coast) Crangon fishing fleet is composed of around 90 vessels, mainly twin beam trawlers, operating from the ports of Kings Lynn, Boston, Grimsby and some other minor ports. The fleet is far from homogenous and vessels range from small open type boats, medium sized ranged to much larger vessels. All of the vessels have engine powers of less than 300 HP (220 kW). The vessels operate in fishing grounds in the coastal waters from the Humber down to the Wash and Norfolk coast. Presently about 40% of the fleet (by effort) use veil (sieve) nets (50 / 60 mm fully stretched mesh inside diameter) which reduces the level of capture of unwanted by-catches / discards (Revill, 1997). The catches are landed on deck or hoppers and sorted through a deck riddling system to remove unwanted by-catches and separate out the marketable *Crangon crangon,* which are then washed and cooked onboard.

3. Methods

3.1 Discard sampling programme

A total of 61 commercial voyages, onboard 12 different fishing vessels from the study fishery, were undertaken between 1993-1996. During this period, 265 tows were examined. Quantitative assessments of levels of discarded commercial species of fish were made from each tow. The discarded fish were lengthed and assigned ages using age - length keys. The trawled area of each tow was calculated, based on a function of aggregate beam length, vessel speed over the ground and duration of tow.

3.2 Raising discarded fish numbers to fleet level

The discarded fish numbers were pooled on a quarterly basis and raised to fleet level using trawled area as a basis for the various raising factors. The fleet total trawled area, and variables such as the seasonal distribution of effort, fishing vessel size, type and class, the variations in fishing behaviour patterns and grounds, trawling time lost due to fastners, snags etc. were all accounted for, during the calculation of the various raising factors. The majority of this information pertaining to these variables was sourced from the extensive study performed on this fleet (Revill, 1997) and other sources (Anon 1995) (Anon 1995a).

3.3 Correcting for recruitment variations and year class strength of the fish species

In an attempt to eliminate the variations in discarding levels that occur from year to year, due to fluctuating year class and recruitment strengths, a series of correction factors were derived to smooth out this source of variation. This was achieved (for plaice and sole only) using trends in North Sea pre recruit indices, specific to the study fishery area (CEFAS (Lowestoft) North Sea Annual Ground fish surveys).

3.4 Modelling the discard data

The corrected discard data was subsequently modelled using yield / recruit based modelling to make a variety of predictions relating to the likely impacts of this source of discarding (in both economic and biological terms). The modelling attempted to answer the following questions:

- 'What would happen to the fish if they were not caught and discarded in such great numbers? (i.e. by using more selective fishing gears)'
- 'What would be the economic / biological benefits and deficits to fisheries if this current level of discarding were to be reduced?'

3.4 Modelling variables

A schematic description, figure (1) details the various stages of the modelling process. During the modelling, it was attempted as far as possible to take account of the following variables.

3.4.1 Losses that would be incurred due to natural (M) & fishing (F) mortalities

Estimates of M and F were sourced from (Anon, 1995b) and (Turnpenny et al, 1983).

3.4.2 Losses that would be incurred due to further, later discarding by other fleets (D)

Estimates of D were obtained from (Anon, 1994) and personal communications (Grant Course, CEFAS (Lowestoft)).

3.4.3 Weight to age relationships of different species

These relationships were sourced from (Anon, 1995b).

3.4.4 Average fish market values of fish species

These were based on average fish market prices from the ports of Urk, Newlyn, Ijmuiden and Lowestoft (Fishing News, fish market price information 1996-1997).

3.4.5 The performance characteristics of selective fishing gears (Veil nets)

This was based on experimental data (Graham, 1997) (Revill, 1997a). A summary table of the performance characteristics is detailed in table (1).

3.4.6 Discard survival rate

The discard survival rate was assumed to 0 % during the modelling.

3.4.7 Survival rate of fish passing through more selective fishing gears

The survival rate of fish escaping capture by passing through more selective fishing gears was assumed to be 100% during the modelling.

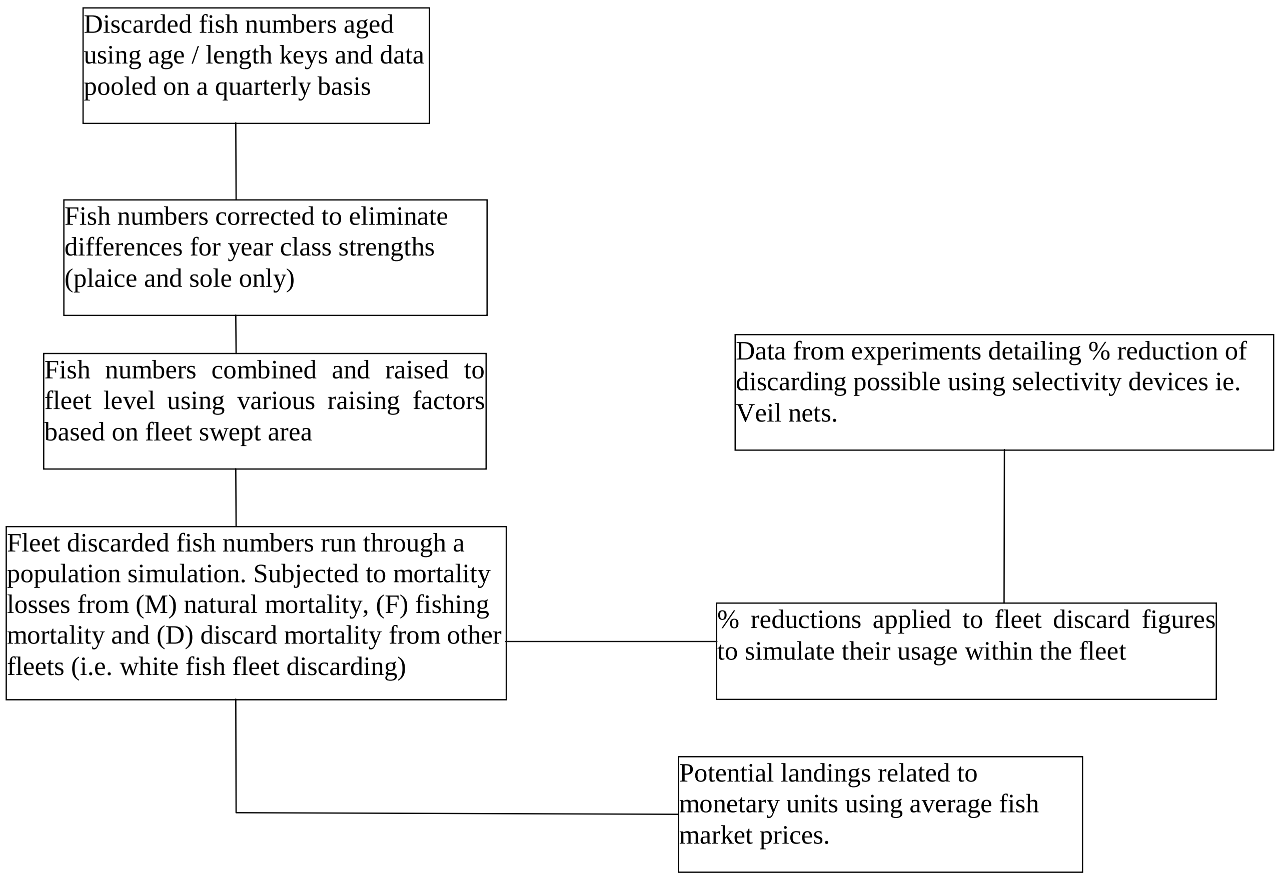

Table 1 The % reductions observed in the capture of discards using 50/60 mm veil nets in the U.K. (East coast) Crangon crangon fishery

Observed % reduction in discard levels at age								
	Plaice		Sole		Cod		Whiting	
Age	0	1	0	1	0	1	0	1
1st quarter of year		40%		65%		75%		40%
2nd quarter of year		50%		65%		75%		40%
3rd quarter of year	20%	95%	20%	75%	25%	100%	0%	65%
4th quarter of year	40%	95%	30%	75%	35%	100%	30%	75%

4. Results

4.1 The U.K.(East coast) *Crangon* fishing fleet effort distribution

During 1995, the annual fleet effort was determined to be 3,238 Km^2 as trawled area (Revill, 1997). The distribution of effort throughout the fleet was found to be considerably skewed with much of the effort attributable to only a few of the larger sized vessels. Many vessels were also identified to be virtually inactive in terms of their relative fishing effort (Revill, 1997). Lost fishing time at sea (due to fouled gear, snags etc.) was estimated to be 2.8 % (Revill, 1997a), reducing the actual 1995 fleet effort trawled area to 3,147 Km^2.

4.2 The numbers of fish discarded by the U.K.(East coast) Crangon fishing fleet

The table (2) details the estimated numbers of fish (at age) discarded by this fleet annually (at 1995 effort levels) as determined from the discard sampling programme.

Table 2 The No's of fish (in millions) discarded at age by the U.K.(East coast) Crangon fishing fleet at 1995 effort levels

Species	Age 0 (x million)	Age 1 (x million)	Age 2 (x million)	All ages (x million)
Sole (Solea solea)	0.47	0.82	0.11	1.4
Plaice (Pleuronectes platessa)	9.7	5.6	0.04	15.3
Cod (Gadus morrhua)	2.1	0.65	*negligible*	2.8
Whiting (Merlangius merlangus)	14.7	3.2	0.06	18.0

4.3 The estimated lost landings and revenues associated with current levels of discarding

The modeling of the discard data predicted the economic consequences in terms of potential lost landings and revenue associated with current levels of discarding at 1995 effort levels, details of which are given in table (3).

4.4 The predicted additional landings associated with the more widespread use of more selective fishing gears

Table 4 details the predicted additional landings that could be associated with 100% full fleet usage of veil nets of 50 or 60 mm mesh size.

Table 3 Predicted annual lost landings & revenue due to current levels of discarding by the fleet

Species	Estimated yield loss due to present level of discarding (NB: Current status of fleet - 40% of fleet effort using veil nets)	
	Annual predicted lost landings (tonnes)	Fish market value of annual lost landings (£ x 1,000)
Whiting	80	51
Cod	281	388
Sole	76	565
Plaice	561	983
All species	998	1,987

Table 4 The predicted additional annual landings and associated market values that could be attributable to a 100% fleet usage of veil nets (50 / 60mm)

Species	Predicted additional annual landings (tonnes)	Fish market value of additional landings (£x 1000)
Whiting	47	£ 30
Cod	295	£ 408
Sole	73	£ 540
Plaice	323	£ 566
All species	738	1,544

5. Discussion

5.1 The economic and biological impacts of discarding - Plaice

The population modelling estimates that discarding of plaice by this fleet presently results in an annual loss of plaice landings equivalent to 561 tonnes (worth £983,000). The figures have been adjusted to eliminate differences for year class strength variations. The discarding of '1' group plaice is perhaps the most significant in terms of impact and numbers, in that these fish have a much lower natural mortality than '0' group fish. Although '0' group fish are discarded in higher numbers, their high natural mortality rate means than the majority of '0' group plaice would have died anyway even if they had not been caught and discarded by the Crangon fishing fleet. The '1' group fish are much larger than '0' groups and as such can be more readily eliminated by selective fishing gears such as veil nets. Around 40% of the fleet (by effort) already use veil nets, reducing discard levels and contributing 130 tonnes (worth £228,000) to present plaice landings. If the remaining 60% of the fleet were to use veil nets the predicted reduction in discarding would result in an additional 193 tonnes of plaice worth £338,000 being landed annually without any increase in fishing effort.

5.2 The economic and biological impacts of discarding - Whiting

Whiting are caught and discarded in large numbers by this fleet. The low commercial value of this species and the very high natural mortality rates associated with '0' and '1' groups essentially minimise the impacts of this discarding. It is estimated that the great majority of these whiting would die anyway from natural mortality even if they were not caught and discarded by this fleet. Whiting are also discarded in large numbers by other fleets. The economic losses associated with the present level of Crangon related whiting discarding is estimated to be minimal, at around £51,000 (equivalent to 80 tonnes of lost landings). This assumes if the fish were not caught by the shrimp fleet, a high level of discarding by other fleets would occur.

5.3 The economic and biological impacts of discarding - Cod

Juvenile cod appear to have been caught and discarded in significant numbers in this fishery since late 1995. Previous to this, records indicate that they have not been caught in such numbers before. It was not possible to accurately adjust and compensate the results for year class strength variations within this work. As a result the population models for cod are based on the assumption that discarding of this species remains at the current recent high levels, which may be an erroneous assumption. If however, discarding continues at current levels, the associated economic losses are estimated to be around £388,000 (281 tonnes of landings) per year.

5.4 The economic and biological impacts of discarding - Sole

Sole is a high value species and current discarding by the shrimp fleet results in an estimated loss of 76 tonnes of potential sole landings (worth £565,000). This is equivalent to 10% of the total 1997 U.K. T.A.C. (North Sea / channel) which was set at 770 tonnes. The figures have been adjusted to eliminate differences for year class strength variations. Once again a significant reduction in discarding can be achieved by using more selective fishing gears and predictions indicate an increase in landings would result.

5.5 The economic and biological impacts of discarding - All species combined - Veil nets

Presently, some 40% of the U.K. (East coast) *Crangon* fleet (by effort) voluntarily use veil nets. There is no requirement for these U.K. skippers to use this gear to date, and as such, usage could fall or rise in the future. It is demonstrable that the veil nets presently in use, do reduce discarding of commercially important and non commercial species of fish. Even with this number of veil nets in use, the present economic costs of discarding by the Crangon fleet (of cod, whiting, plaice and sole only) is estimated to be equivalent to £ 2 million per year in lost landings revenue. There appears to be a measurable justification to ensure that all vessels in this fleet use veil nets in the future.

5.6 Other selectivity devices - Sorting grids

It has been shown (Graham, 1997) that sorting grids in this fishery can also reduce discarding in this fishery and may offer superior percentage reduction in the capture of unwanted discards.

5.7 Losses associated with the use of more selective fishing gears

The 'losses' associated with the use of more selective fishing gears should be considered, and possibly offset against the 'gains'. For example there is a 10 - 15 % loss of target Crangon capture (by weight) associated with the use of veil nets / grids (Graham, 1997) (Revill, 1997a). Should veil nets be introduced throughout this fleet (i.e. 100% usage), the economic value of this loss to the shrimp fishermen collectively, is estimated would be in the order of £300,000 per year in lost Crangon landings (Revill, 1997a). Overall, the gains substantially exceed the losses, however, as the beneficiaries of the predicted gains are not the shrimp fishermen themselves, discard reduction measures may not receive their support.

5.8 Discarding in other fleets

This study has examined discarding solely within the U.K. (East coast) *Crangon* fishing fleet. It is important to put the findings in this study into perspective, particularly in relation to other fleets. The Crangon fishery in the U.K.(East coast) is relatively small and U.K. shrimp landings amount to less than 5% of the total European landings (Van Marlen et al, 1997). During 1996, over 900 million juvenile plaice alone, were discarded by the combined European Crangon fleets in the North Sea alone (Van Marlen et al, 1997). There is quantifiable discarding of commercial species in other fisheries, such as that which occurs with the white fish beam trawlers, demersal trawlers and Nephrops fleets. It is likely therefore, that discarding in general does have significant measurable economic and biological impacts. If discard reduction measures were to be introduced into a fishery, such as the use of more selective fishing gears, the benefits to stocks may be significant enough to partially offset financially limiting management strategies such as effort reduction schemes, quota restrictions etc.

6. Conclusion

The U.K. (East coast) *Crangon crangon* fishery currently discards large numbers of juvenile species of commercial fish. The annual yield loss resultant from this discarding is estimated to be £ 2 million (998 tonnes of lost landings of plaice, sole, cod and whiting). If all of the vessels in this fishery were to fit veil nets into their beam trawls, the subsequent reduction in discarding would result in an estimated £ 1.5 million (738 tonnes) of fish being caught and landed each year, with no additional fishing effort. There would also be an addition in numbers to the spawning stocks biomasses. Discarding in fisheries is quantifiable. If quantified, the data can be modelled to determine the likely biological and economic consequences resultant from that source of discarding. Discard data can be modelled to identify those discarded species at age, which are most vulnerable and important in an economic and biological sense. This type of analysis can lay the foundation for performance criteria for management strategies, such as the development of more selective fishing gears to be developed in an efficient focused and targeted manner.

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Another Way of Looking at Fisheries Management: the Computable General Equilibrium Models [1]

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Abstract

In the current literature, fish markets are analysed through bioeconomic models within the context of partial equilibrium. In the present paper, we propose a new approach of fish market modelling based on a Computable General Equilibrium Model (CGEM). Such a model is looking at interactions between the seafood market and all other commodity markets in the economy. Therefore, prices are determined endogeneously by both supply and demand forces at the general equilibrium level. Two CGEM are proposed, one dealing with open access in the fishery, the other including management measures. A theoretical demonstration shows that management is an optimal solution whereas open access is sub-optimal. An economic explanation of this fact is put forward.

Introduction

Dans la littérature traditionnelle, le secteur halieutique est toujours analysé aux travers de modèles bioéconomiques dans un contexte d'équilibre partiel. Dans ce papier, nous proposons une nouvelle approche de la modélisation du marché des ressources renouvelables basée sur la construction d'un modèle d'équilibre général. Ce type de modèle, très utilisé en économie de l'environnement et en économie agro-alimentaire, a pour principal avantage de tenir compte de toutes les interactions d'offre et de demande que ce soit à l'intérieur d'un secteur spécifique ou entre les secteurs d'une même économie. Il a aussi pour avantage d'endogénéiser les prix des différents biens résultant des comportements d'offre et de demande.

A la suite des travaux de Copes P. (1970), Brander et Taylor (1995, 1996, 1997) et Emami et Johnston (1996), nous proposons de construire deux modèles d'équilibre général: l'un en présence d'une ressource renouvelable en libre-accès, l'autre avec une ressource gérée. Ces modèles seront l'occasion de clarifier quelles peuvent être les fonctions d'offre et de demande pour chacun des marchés.

[1] This research has been carried out with the support of the Commission of the European Communities (FAIR programme). It does not necessarily reflect its views.

Nous étudierons ensuite les différents équilibres de marché et, grâce à une démonstration théorique fondée sur des concepts purement économiques, nous montrerons qu'un équilibre en présence d'une ressource gérée est efficace et optimal alors que le marché d'une ressource non gérée est inefficient bien que pouvant se situer en équilibre.

Modèle d'équilibre général et fonction biologique de la ressource

L'intérêt de notre travail réside dans l'utilisation d'un modèle d'équilibre général calculable. Nous proposons d'étudier cette nouvelle approche en y intégrant des fonctions biologiques communément utilisées en économie des pêches.

Les modèles d'équilibre général appliqués aux ressources renouvelables

Les modèles d'équilibre général - MEGC - ont pour vocation d'analyser l'ensemble d'une économie en tenant compte des différentes relations existantes entre les marchés. Cette approche a pour fondements théoriques les travaux sur l'équilibre général initiés par Walras et formalisés par Arrow-Debreu.

Depuis le début des années 80, on assiste à un développement de ce type de modélisation visant principalement à répondre à une certain nombre de problèmes économiques très spécifiques (Borges, 1986) - impact de la libéralisation des échanges, problèmes énergétiques et agricoles, impact d'une modification de la fiscalité, problèmes liés à l'environnement ... La fonctionnalité des MEGC n'étant plus à démontrer, tous les grands organismes internationaux et nationaux ont engagé des recherches et des travaux visant à se doter d'un tel outil. Citons par exemple le modèle environnemental GREEN de l'OCDE, le modèle agro-alimentaire MEGAAF de l'Inra visant à étudier la PAC, ... A notre connaissance, de telles recherches n'ont pas encore été menées dans le secteur des pêches si ce n'est les quelques travaux de Brander et Taylor visant à étudier le commerce international des ressources renouvelables. C'est pourquoi, nous proposons la construction d'un MEGC axé essentiellement sur le marché du secteur halieutique dont la principale particularité est le caractère renouvelable de la ressource.

Pour ce faire, comme pour tout modèle d'équilibre, notre modèle tente de décrire les interactions entre les agents économiques qui ont pour objet d'optimiser leur revenu compte tenu de leurs contraintes respectives. La confrontation des fonctions d'offre et de demande sur tous les marchés permet d'atteindre des niveaux d'équilibre correspondant à une répartition optimale des ressources biologiques et productives: par définition, à long terme, tous les marchés sont en équilibre que ce soit le marché du travail, le marché du bien ressource ou le marché du bien manufacturier. La logique intrinsèque à ce modèle est la présence d'un comportement microéconomique d'optimisation des agents qui permet une répartition efficace et optimale des différentes ressources.

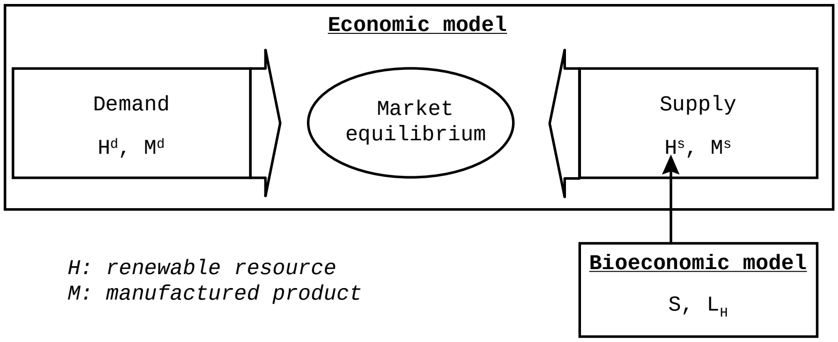


Figure 1 *Structure du modèle d'équilibre général appliqué aux ressources renouvelables*

La particularité du modèle réside dans l'introduction dans le programme du producteur d'une fonction permettant de simuler le caractère renouvelable de l'input. Cette fonction n'est autre qu'une fonction biologique souvent étudiée et utilisée dans la littérature en économie des pêches.

La fonction biologique de la ressource

La fonction biologique de la ressource peut être déduite des travaux précurseurs de Gordon (1954) et Schaefer (1957). Ces auteurs supposent que la variation du stock de la ressource $\dot{S}$ dépend du différentiel entre le taux de renouvellement G et le taux d'exploitation H.

$$\dot{S} = G - H \qquad (1)$$

avec

$$G = G(r, S, K)$$
$$H = (\alpha, S, L_H)$$

Traditionnellement, le *taux de renouvellement* de la ressource G est une fonction logistique dépendante de trois variables.

$$G(S) = rS\left(1 - \frac{S}{K}\right) \qquad (2)$$

- r le *taux de croissance intrinsèque* de la ressource.
- K la taille maximale du stock de la ressource
- S le stock de la ressource.

Le *taux d'exploitation* de la ressource H dépend du niveau du stock et de l'effort de travail.

$$H(S) = \alpha S L_H \qquad (3)$$

- α coefficient de prenabilité - proxy du niveau technologique des entreprises
- L_H le niveau de travail nécessaire à l'exploitation de la ressource
- S le stock de la ressource.

L'équilibre biologique de la ressource est atteint lorsque le taux d'exploitation de la ressource est égal à son taux de renouvellement naturel. A ce point d'équilibre, la production des entreprises est compatible avec le rythme biologique de la ressource; le stock ne varie plus. D'après les équations (2) et (3), celui-ci peut s'écrire:

$$\dot{S} = 0 \Leftrightarrow G = H$$

$$H = rS\left(1 - \frac{S}{K}\right) \qquad (4)$$

$$S = K\left(1 - \frac{\alpha}{r} L_H\right) \qquad (5)$$

De plus d'après (4) et (5), on en déduit la courbe de Schaefer appelée aussi *loi rendement - effort*:

$$H = \alpha K L_H \left(1 - \frac{\alpha}{r} L_H\right) \qquad (6)$$

D'après la structure du modèle d'équilibre général, ces différentes équations vont être intégrées dans la fonction d'offre des producteurs.

Les modèles à long terme du marché de la ressource

Il convient de distinguer le marché d'une ressource en libre accès d'un marché dont la ressource est gérée. Une comparaison des différents équilibres et optima fera l'objet de la quatrième section.

Les hypothèses des modèles

Par hypothèse, les modèles ont une structure 2 agents (le consommateur et le producteur), 2 biens (le bien ressource H et le bien manufacturier M), 2 facteurs (le stock S de la ressource et le travail L).

Pour notre démonstration, nous prenons comme numéraire le prix du bien manufacturier. Ainsi, soit p_H le prix du bien ressource et p_M le prix du bien manufacturier, le prix relatif du bien ressource comparativement à celui du bien manufacturier devient $p = p_H / p_M$.

Nous supposons que le facteur travail est mobile entre les secteurs. Ainsi, la rémunération de ce facteur est indépendante du secteur considéré et égale à l'unité.

La *fonction de production du bien ressource* est dépendante des deux inputs disponibles dans notre économie, le stock de la ressource et le facteur travail. Nous utilisons pour ce faire la fonction (3).

$$H(S) = \alpha S L_H \qquad (7)$$

La *fonction de production du bien manufacturier* ne dépend que du facteur travail. Par hypothèse et puisque le prix du bien manufacturier est le prix de référence, nous supposons que la productivité marginale de ce facteur est égale à l'unité. Ainsi, la fonction de production de ce bien s'écrit:

$$M = L_M \qquad (8)$$

Dans le cadre d'un *modèle d'équilibre général*, nous supposons, par définition, que tous les marchés sont à l'équilibre. Ainsi, nous avons[1]:

- sur le marché du bien ressource: $H^d = H^S$
- sur le marché du bien manufacturier: $M^d = M^S$
- sur le marché du travail: $L = L_H + L_M$

Le modèle en libre-accès

Ce type de marché est caractérisé par l'existence d'une ressource soumis à des droits de propriété mal définis. Nous étudions successivement le comportement du consommateur puis celui du producteur sur les marchés de la ressource et du bien manufacturier.

Programme du consommateur

Selon la théorie du consommateur, chaque individu maximise son utilité en fonction de sa contrainte budgétaire. Nous supposons que la fonction d'utilité est de type Cobb-Douglas, homogène de degré 1. Le programme s'écrit donc:

$$Max\ U(H, M) = H^{\beta} . M^{1-\beta}$$
$$s.c.\ R = p.H + M$$

[1] D: demande, S: offre

avec

- *U* l'utilité du consommateur
- *H* la consommation du bien ressource
- *M* la consommation du bien manufacturier
- *R* le revenu du consommateur. Par définition, $R = wL$ avec *w* le salaire unitaire (*w=1*) et *L* le nombre de salarié.
- *p* le prix relatif du bien ressource
- β l'élasticité de consommation. Ce paramètre peut-être assimilé à un paramètre de goût décrivant la préférence pour la consommation du bien ressource ($0 < \beta < 1$).

La résolution de ce programme permet d'écrire les fonctions de demande respectivement du bien ressource et manufacturier suivantes:

Demande du bien H $$H = \frac{\beta L}{p} \qquad (9)$$

Demande du bien M $$M = (1-\beta).L \qquad (10)$$

Conformément à la théorie économique, la demande du bien ressource traduit le fait qu'une augmentation du prix entraîne effectivement une diminution des quantités demandées. De plus, à même niveau de prix, une préférence de plus en plus importante pour le bien ressource et / ou une augmentation de la pression démographique a pour conséquence une augmentation des quantités demandées.

Quant à la demande du bien manufacturier, elle dépend négativement du paramètre de goût et positivement de la pression démographique.

Programme du producteur

le bien ressource

Nous supposons que le marché est en concurrence. Ainsi, à l'équilibre, conformément à la théorie du producteur, les entreprises épuisent toute la rente disponible. Le profit global de ce secteur est donc nul. Nous obtenons:

$$\pi = RT - CT$$
$$\pi = p.H - w.L_H$$
$$\pi = 0 \Rightarrow p = \frac{wL_H}{H}$$

soit en intégrant la fonction de production (7) et soit *w=1*, le prix s'écrit:

$$p = \frac{1}{\alpha S} \tag{11}$$

A long terme, le modèle bioéconomique permet d'exprimer le taux d'exploitation possible de la ressource en fonction du niveau du stock - équation (4). Les équations (4) et (11) nous donnent la fonction d'offre du bien ressource.

Offre du bien H $$H = rK\left(\frac{1}{\alpha Kp}\right)\left(1 - \frac{1}{\alpha Kp}\right) \tag{12}$$

D'après la terminologie utilisée par Copes P. (1970), cette fonction d'offre est appelée *backward-bending supply curve*. Sa forme sigmoïdale en fait une fonction d'offre atypique en économie. Elle est en effet croissante sur l'intervalle de prix $\left[\frac{1}{\alpha K}, \frac{2}{\alpha K}\right]$ puis décroissante sur $\left[\frac{2}{\alpha K}, +\infty\right[$.

le bien manufacturier
La courbe d'offre du bien manufacturier se déduit de l'équilibre sur le marché du travail et de l'équation d'équilibre (17). Nous obtenons:

Offre du bien M $$M = (1-\beta).L \tag{13}$$

L'équilibre du marché des ressources en libre-accès
Les équations d'offre et de demande des deux biens permettent d'écrire les différents équilibres de marché.

Equilibre sur le marché ressource

$$\begin{cases} H^{eq} = \alpha\beta KL\left(1 - \frac{\alpha\beta L}{r}\right) & (14') \\ p^{eq} = \dfrac{1}{\alpha K\left(1 - \frac{\alpha\beta L}{r}\right)} & (14'') \end{cases}$$

Equilibre sur le marché manufacturier

$$\begin{cases} M^{eq} = (1-\beta)L & (15') \\ p^{eq} = 1 & (15'') \end{cases}$$

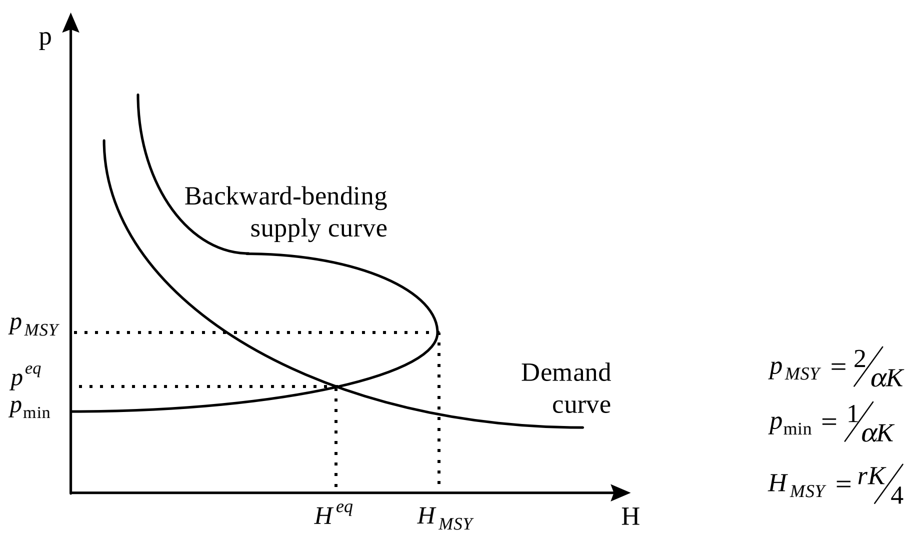
A partir des équations (11) et (14'), nous obtenons le stock d'équilibre

$$S^{eq} = K\left(1 - \frac{\alpha\beta L}{r}\right) \tag{16}$$

puis l'équation du facteur travail alloué à la production de la ressource.

$$L_H = \beta L \tag{17}$$

Notons que la pente positive (négative) de la courbe d'offre correspond à une sous-exploitation (sur-exploitation) de la ressource. Le point de recourbement de cette fonction est égal au niveau d'exploitation maximum soutenable H_{MSY}.



Graphique 1 Le marché des ressources renouvelables en libre accès

Proposition 1

En libre-accès, la courbe d'offre est à pente positive - sous-exploitation - puis à pente négative - sur-exploitation. Dans ce dernier cas, une augmentation exogène de la demande entraîne une hausse des prix accompagnée d'une baisse des quantités offertes. La sur-exploitation de la ressource est alors amplifiée.

Le modèle avec une ressource gérée
La caractéristique de ce marché est la présence d'une ressource soumis à des droits propriétés bien définis. A l'image des travaux de Brander et Taylor (1995), nous proposons d'étudier le comportement du marché lorsque l'organisme gestionnaire gère la ressource en instaurant une taxe à la production.

L'objectif de cet organisme est donc de répartir de façon optimale les ressources (input) disponibles dans l'économie tout en préservant le niveau des stocks. Les ressources globales de l'économie sont différentes du modèle précédent. En effet, l'instauration d'une taxe à la production engendre des ressources supplémentaires pour l'ensemble de la société. L'ensemble du revenu des agents s'écrit de ce fait:

$$R = wL + t_x H \tag{18}$$

Cette équation signifie que le revenu global est composé de l'ensemble des salaires et du revenu de la taxe par unité produite.

Programme du consommateur
Comme dans le précédent modèle, le consommateur maximise son utilité sous contrainte de son revenu. Cependant, dans notre modèle à deux agents, le revenu du consommateur est augmenté du revenu de la taxe. Ainsi nous avons le programme suivant:

$$Max\ U(H, M) = H^{\beta} . M^{1-\beta}$$
$$s.c.\ R = p.H + M$$
avec $R = wL + t_x H$

La résolution de ce programme permet d'écrire les fonctions de demande suivantes:

Demande du bien H $$H = \frac{\beta L}{p - t_x \beta L} \tag{19}$$

Demande du bien M $$M = \left(\frac{p}{p - t_x \beta L} \right)(1-\beta). L \tag{20}$$

Programme du producteur

le bien ressource
L'objectif de l'organisme gestionnaire est d'optimiser l'utilisation de l'ensemble des ressources de l'économie, il a donc pour objectif de maximiser l'utilité globale de la société.

Le programme du producteur est donc:

$$\begin{aligned}
&Max\ R = pH + M \\
&s.c.\ H = rS\left(1-\frac{S}{K}\right) \\
&\quad M = L_M
\end{aligned}$$

A l'équilibre biologique de la ressource, l'équation (5) et l'équilibre sur le marché du travail nous permettent d'écrire:

$$\begin{aligned}
&M = L - L_H \\
&M = L - \frac{r}{\alpha}\left(1-\frac{S}{K}\right)
\end{aligned}$$

La fonction de profit total s'écrit donc:

$$R = pH + M$$

$$R = p.rS\left(1-\frac{S}{K}\right) + L - \frac{r}{\alpha}\left(1-\frac{S}{K}\right) \qquad (21)$$

L'objectif étant de maximiser le profit et étant donné qu'à long terme le facteur stock est endogène, nous pouvons calculer la dérivée partielle du profit par rapport au stock.

Nous obtenons

$$\frac{\partial R}{\partial S} = 0 \Rightarrow S = \frac{1}{2}\left(K + \frac{1}{\alpha p}\right) \qquad (22)$$

De cette équation associée à l'équation (4), nous en déduisons la fonction d'offre du bien produit à partir d'une ressource gérée.

Offre de LT du bien H $\quad H = \frac{rK}{4}\left[1 - \frac{1}{(\alpha K p)^2}\right] \qquad (23)$

Cette fonction est une fonction typique en économie en ce sens qu'elle relie positivement le prix et les quantités.

le bien manufacturier
Comme pour le modèle précédent, les différents marchés sont équilibrés. Nous retrouvons donc sur le marché du travail l'équation $L = L_H + L_M$ avec $M = L_M$. Nous en déduisons de ces égalités et de l'équation (5) l'offre du bien manufacturier:

Offre à LT du bien M $$M = L - \frac{r}{2\alpha}\left(1 - \frac{1}{\alpha K p}\right) \quad (24)$$

L'équilibre du marché des ressources gérées

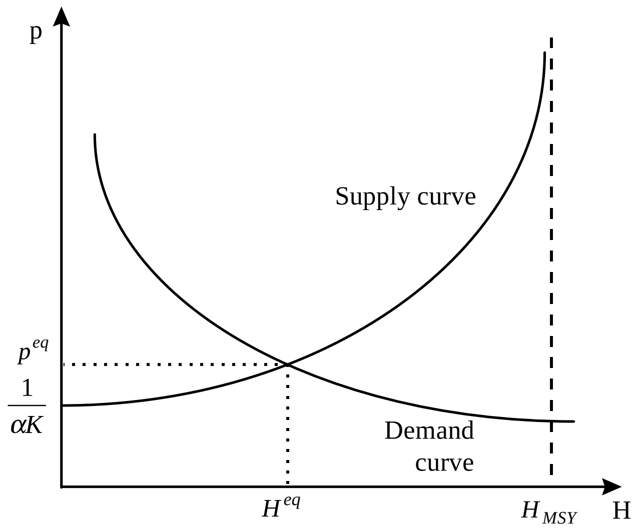
Les différents équilibres de marché sont quelque peu complexes à calculer du fait de l'introduction d'une taxe. Toutefois, nous signalons au lecteur que le prix d'équilibre peut-être exprimé de la façon suivante:

$$p = \frac{\beta(2\alpha L - r) + \sqrt{4\alpha\beta^2 L(\alpha L - r) + r^2}}{\alpha(1-\beta)Kr} \quad (25)$$

Les autres valeurs d'équilibre peuvent être calculées en utilisant les différentes fonctions d'offre et demande. Notons toutefois que la taxe optimale pour gérer la ressource est:

$$t_x = \frac{p}{\beta} - \frac{L}{H}$$

La représentation graphique permet de mieux comprendre le marché d'une ressource gérée. Ce marché est donc composé d'une demande à pente négative et d'une offre typique à pente croissante.



Graphique 2 Le marché des ressources renouvelables gérées

Notons enfin, que tous les équilibres de marché correspondent à un niveau des stocks supérieur au niveau du *MSY*. Ceci traduit effectivement le fait que l'organisme gestionnaire alloue efficacement toutes les ressources productives tout en respectant le caractère renouvelable de la ressource.

Proposition 2

En présence d'une ressource gérée, la courbe d'offre est toujours à pente positive. Elle correspond à une situation où le stock est strictement supérieur au stock maximum soutenable.

Equilibre et optimum

Dans cette dernière section, nous comparons les différents équilibres afin de déterminer quel peut-être le marché le plus efficace économiquement et biologiquement. Dans un premier temps, une comparaison économique et biologique des différents équilibres est faite afin d'évaluer dans un second temps l'optimalité de ces équilibres. Ces deux notions nous permettent de dégager des conclusions quant à l'efficacité des deux systèmes de gestion.

Libre-accès vs gestion de la ressource: le concept d'utilité

Dans cette section, nous ne développons pas tous les détails de calcul qui sont quelque peu fastidieux, seuls les principaux résultats sont présentés.

La comparaison des équilibres pour le bien-être de l'économie nécessite de tenir compte du rapport des utilités des deux modes de gestion. Pour ce faire, nous pouvons écrire[1]:

$$\frac{U^{MG}}{U^{OA}} = \frac{\left(H^{MG}\right)^{\beta} . \left(M^{MG}\right)^{1-\beta}}{\left(H^{OA}\right)^{\beta} . \left(M^{OA}\right)^{1-\beta}}$$

L'introduction des différentes demandes permet d'écrire les utilités indirectes suivantes:

$$\frac{UI^{MG}}{UI^{OA}} = \frac{\left(\frac{R^{MG}.\beta}{p^{MG}}\right)^{\beta} . \left(R^{MG}.(1-\beta)\right)^{1-\beta}}{\left(\frac{R^{OA}.\beta}{p^{OA}}\right)^{\beta} . \left(R^{OA}.(1-\beta)\right)^{1-\beta}}$$

Nous en déduisons:

$$\frac{UI^{MG}}{UI^{OA}} = \frac{R^{MG}}{R^{OA}} . \left(\frac{p^{OA}}{p^{MG}}\right)^{\beta} \qquad (26)$$

Nous laissons au lecteur le soin de vérifier que quelques soient R^{MG}, R^{OA}, p^{OA}, p^{MG}, le rapport des utilités indirectes est toujours supérieur à l'unité. Ainsi:

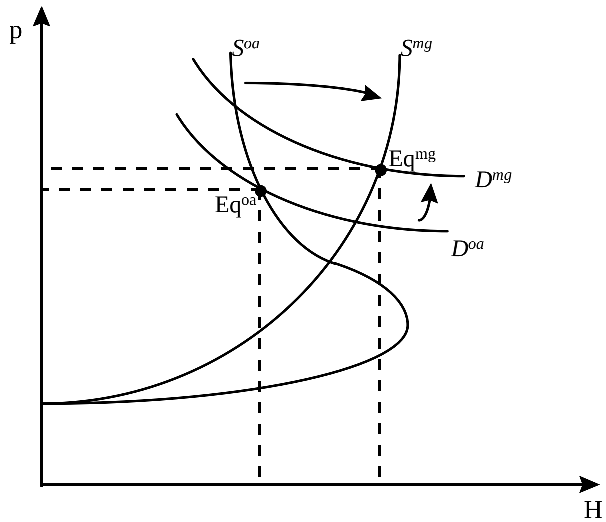
$$UI^{MG} > UI^{OA} \qquad (27)$$

Cette inégalité est consécutive à deux effets: un effet revenu R^{MG}/R^{OA} et un effet gestion $\left(p^{OA}/p^{MG}\right)^{\beta}$.

- *Effet gestion*: la gestion d'une ressource a pour premier effet de modifier la courbe d'offre des producteurs (graphique 3). En effet, gérer la ressource permet de passer d'une *backward bending curve* S^{oa} (ressource non gérée) à une courbe d'offre à pente positive S^{mg} (ressource gérée). Il en résulte une augmentation des prix du fait de l'introduction d'une taxe à la production.

[1] MG: ressource gérée (management), OA: ressource en libre-accès (open-access).

- *Effet revenu*: l'introduction d'une taxe permet dans un second temps d'augmenter le revenu national. Ceci a pour effet de déplacer la courbe de demande vers le haut (D^{oa} vers D^{mg}).



Graphique 3 Libre-accès versus gestion de la ressource

Nous pouvons démontrer qu'indépendamment des conditions initiales des deux marchés, l'effet revenu est toujours supérieur à l'effet gestion ce qui se traduit lors du passage d'une ressource non gérée à une ressource gérée, par une augmentation des prix et des quantités d'équilibre.

Proposition 3

Le passage d'une ressource non gérée à une ressource gérée a un effet revenu supérieur à l'effet prix, l'effet revenu étant consécutif à l'augmentation des capacités financières globales de l'économie alors que l'effet prix est dû à l'introduction d'une taxe à la production permettant de gérer la ressource. Le bien-être global de l'économie en présence d'une ressource gérée est alors amélioré.

De plus, le stock de la ressource gérée est toujours supérieur au stock maximum soutenable.

L'optimum économique des équilibres de marché

Le calcul des optima nous oblige à adopter une nouvelle représentation des marchés. Il convient de déterminer la frontière des possibilités de production - FPP - afin de pouvoir calculer les taux marginaux de substitution entre le bien ressource et le bien manufacturier. La comparaison de ce taux avec le taux de substitution des biens, calculé par le rapport des utilités marginales, permet de conclure si le libre-accès et / ou la gestion est une politique optimale.

A partir de la courbe (6) de Schaefer, de l'équilibre sur le marché du travail et de la fonction de production du bien manufacturier (8), nous pouvons calculer la FPP. Celle-ci peut s'écrire:

Equation de la FPP $$H = \frac{\alpha K}{r}\left[r - \alpha(L - M)\right]\left[L - M\right] \quad (28)$$

ce qui donne le taux marginal de substitution entre les biens:

$$TmS = \frac{\partial H}{\partial M}$$

$$TmS = \left(\frac{\alpha K}{r}\right)\left[2\alpha(L - M) - r\right] \quad (29)$$

A partir des fonctions d'utilité, nous calculons le taux de substitution des biens - TSB.

$$TSB = \frac{Um_M}{Um_H} = \frac{\partial U / \partial M}{\partial U / \partial H}$$

$$TSB = -\frac{1-\beta}{\beta} \cdot \frac{H}{M} \quad (30)$$

Pour le *modèle en libre-accès et le modèle géré*, nous obtenons les taux suivants:

$$TmS^{OA} = \frac{\alpha K}{r}\left[2\alpha\beta L - r\right] \qquad TmS^{MG} = -\frac{1}{p}$$

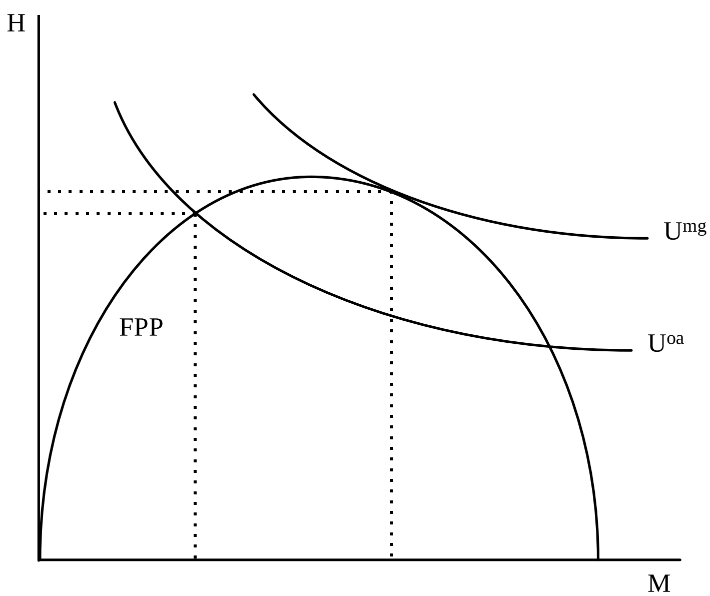
$$TSB^{OA} = \frac{\alpha K}{r}\left[\alpha\beta L - r\right] \qquad TSB^{MG} = -\frac{1}{p}$$

Ces résultats permettent de conclure que la gestion de la ressource est une situation pareto-efficiente alors qu'une ressource en libre-accès ne l'est pas.

$TmS^{OA} \neq TSB^{OA}$

$TmS^{MG} = TSB^{MG}$

Graphiquement, nous pouvons voir que la courbe d'utilité en présence d'une ressource en libre-accès ne permet pas d'atteindre une situation optimale bien qu'il y ait équilibre alors que celle d'une ressource gérée est tangente à la FPP. Un marché avec une ressource gérée est donc optimal au sens de Pareto c'est-à-dire que toutes les ressources disponibles de l'économie sont allouées efficacement dans des différents secteurs productifs.



Graphique 3 Equilibre et optimum des marchés

Proposition 4

Un équilibre en présence d'une ressource non-gérée est toujours sous-optimale alors qu'un équilibre avec ressource gérée est Pareto-efficient. De plus, dans ce dernier cas, l'utilité de l'économie globale est toujours supérieure à l'utilité d'une situation de non-gestion.

Conclusions et extensions

Le papier présenté reconsidère la modélisation du marché des ressources renouvelables et en particulier celui des ressources halieutiques. La prise en compte de ce nouvel outil qu'est le modèle d'équilibre général permet non seulement de tenir compte de tous les aspects d'un marché mais aussi d'étudier les relations existantes entre les marchés. A notre sens, l'originalité d'une telle approche permet de combler les différentes lacunes des modèles bioéconomiques déjà existantes à savoir le manque d'intégration des fonctions de demande et la non prise en compte de l'intégralité des facteurs influants les marchés.

Le premier résultat auquel nous sommes parvenus a consisté à déterminer quelles pouvaient-être les différentes fonctions d'offre et de demande des marchés selon que la ressource est gérée ou laissée en libre-accès. Bien que des auteurs aient déjà eu l'idée de la forme de telle fonction - Copes P. (1970) - peu d'articles en présentent une formalisation précise.

Le second apport de notre travail a consisté à démontrer que les équilibres de marché étaient sous-optimales et donc économiquement inefficaces en présence d'une ressource non gérée mais le devenaient si la ressource était gérée. Un tel résultat n'est en soi pas nouveau, mais il a le mérite de tenir compte, dans le même modèle, des différentes variables d'offre et de demande.

Finalement, ces différents résultats ont le mérite de pouvoir être utilisés à des fins de recommandations de politiques économiques. En effet, la présence des comportements d'offre et de demande dans les équilibres de marchés permettra dans de futurs travaux de mieux comprendre l'influence de chacune des variables dans le formation des prix, dans l'internationalisation des marchés et globalement dans tous les aspects socio-économiques du secteur halieutique.

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Fisheries management by property rights

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Abstract

The paper describes the significance of property rights for the fishery sector. Property in this respect is not considered as an asset in the stock of fish but as a stream of benefits, resulting from the right to fish. Property rights are frequently confused with individual rights but they also may include state property.

Different influences on property rights regimes are distinquished on the one hand and on the other hand, effects of these regimes on policy, the sector's structure and on the attitude of fishermen are summarized. One of these effects, concentration of individual rights, is explained more in detail.

Finally, the paper states that fisheries management policy should start from property rights. In particular, the coming review of the Common Fisheries Policy could be considered more from the viewpoint of property rights.

Main types of property rights

The paper considers property not as an asset in the stock of fish but as a resource flow. Subject of the research are protected rights to a benefit stream, generated with fishing. Rights are considered as 'property rights' when they are exclusive.

Three types of property rights can be distinguished: 1) state property 2) private property and 3) common property. Open access can be seen as a situation of non-property. The decision of the EU in 1976 to establish a coastal zone of 200 miles meant an end of open access for non-EU vessels. The subsequent start of the Common Fisheries Policy (CFP) in 1983 resulted in limiting measures in the framework of the common conservation-, structure- and market policy. Gradually, these measures have evolved into more or less valuable rights in the EU fishing countries.

The Danish fishery is characterized by a flexible, multi-purpose fleet, which relatively easily can move from one fishery to another. Moreover, many of the fisheries are multi-species fisheries. There is an overall limited access to the fishery by the vessel licence and by the requirement to be recognized as a commercial fisherman. These two entitlements are a form of property right, giving access to the benefit stream.

TACs are divided in Denmark into quarterly quotas which secure a spread of fishing activities over the year. These quotas are allocated to individual vessels through rations for a given period. The permissions, specifying the rations, are not fully exclusive so that they have not the character of a property right in the sense of the above mentioned definition.

Some experiments with respect to effort regulation and individual transferable quotas have been conducted but it remains unclear whether these, for the Danish case new management measures, will be implemented in future.

In the Netherlands, the different national TACs have been transformed into individual quota for sole and plaice (in 1976), entitlements to fish on cod and whiting, and permits for the herring- and mackerel fishery. The MAGP has led to a capacity limitation in the form of horsepower licences. All these limitations have evolved towards tradable, valuable private property rights. At the end of 1996 all output rights were transformed into individual transferable quotas (ITQs) and moreover, three types of input rights existed, i.e. horsepower licences, shrimp permits and entitlements for the coastal zone, derived from the EU vessel file registration. The ITQ holders pool their rights since 1993 in eight co-management groups, which are responsible for compliance with the totals of the individual member quotas. The beam trawlers, targeting for flatfish, form the most important segment of the cutter fleet, owning some 85% of the horsepower rights.

The UK had a tradition of virtually open access to fisheries until CFP was established. After that, gradually more and more fleet segments and species were brought under restrictive licencing schemes. Currently the UK approach varies by species and sector with the licences giving access to the fisheries reflecting this. Licences are issued in five main categories depending on the fact of the stock is under pressure and/or under quota. All licences are subject to Ministerial discretion which means that uncertainty remains about the quality and duration of this property right.

A large part of the UK-TACs is managed by the POs on behalf of their members. Quotas are therefore not vested individually (except for the pelagic sector), although track records give some kind of right to a share of the PO-quota.

National capacity management with respect to MAGP requirements has not been effective so far. Only since 1992 under the Sea Fish (Conservation) Act all fishing vessels must be licenced while before that vessels of 10 metres and under were not under any licence scheme. Current national measures deal with the requirement to take out more capacity (120%) in case of replacement of vessels.

Economic characteristics of property rights

Property rights that are exclusive will create scarcity and therefore economic phenomena, such as trade and price formation, may occur.

In the Danish fishery the rights, in the form of limited access, are only weak entitlements. Hence, they have not influenced the development of the fleet significantly. The licence value depends on volume of catch, type of technology used and the quality of the right, including the possibilities of new entrants. The market for licences is difficult to separate from the market for vessels and therefore not very transparent. In general however the decommissioning scheme sets the minimum market price for a vessel licence.

The rations, setting the allowed catch quantity per time period, are not tradable and have therefore virtually no economic value.

Property rights have become a separate production factor in the Dutch cutter fishery. Effective enforcement of the individual quotas has lead to a scarcity of this production factor since 1988. Hence, high prices for ITQs and for other rights were paid. The price of a combined sole/plaice ITQ (a 'permanent' share in the Dutch TAC) rose to a level of NLG 100-130 per kg. in the early nineties, which is at least four times the auction price per kg. for these species. Investments in rights exceeded those in vessels in this period. Most of these purchases of ITQs have been done by the owners of larger (>1500 HP) beam trawlers with the intention of adjusting the rights to the capacity of their vessels.

Investments in these property rights have increased the production costs of the vessels. On the other hand, future profits that may arise from a successful fish stock management can not be dissipated by the entrance of newcomers.

The development of the regulations in the eighties and nineties show an increase of individualisation and flexibility of the rights to meet the economic interests of the industry more adequately.

In the UK, the predominance of the larger vessels is very marked, with vessels over 10 metres catching 95% of the total landed, though they number only a third of the total of vessels.

Property rights generally are not considered to be a significant entry barrier for newcomers in the industry. There are some exceptions however in the pelagic and beam trawl sector where licences can be worth around 30% of the value of the vessel. The pelagic vessels have the most highly valued licences due to the good and stable mackerel and herring quotas as well as the very efficient technology involved.

The existence of the necessary licences is taken by bankers as a pre-requisite in allowing loans but the value of the licences (except when realised in a sale of the vessel) is generally not regarded as part of the capital structure by them or the accountants and consequently not by the tax authorities. The bankers are guided in this respect by the fact that the licences are only issued on an annual basis.

Property rights in agriculture

Property rights in the form of production rights also exist in other industries. The study explores briefly one of the specific agricultural production rights, i.e. milk quota, to consider whether lessons for the fishing industry can be drawn.

In Denmark, one central agency has been established which is responsible for the reallocation of milk quotas between farmers. Quotas are only transferable along with land in cases of sale, inheritance or tenancy. Several (subsidy) schemes have been successfully implemented to help farmers out of the industry and reallocation of their quota by the agency has resulted in concentration of quota-ownership in the Danish dairy industry.

In the Netherlands, a rather extensive trade in individual milk quotas has arisen whereby prices has reached relatively the same level as in the fishery sector, i.e. four to six times the producer (kg.) price. Trade has led to some concentration of milk quotas, as the average milk quota per farm rose by 26% in the period 1984-1992. This increase in scale of production has been less than in Denmark where the average quota per farm went up by 90% in the period 1984-1994. However, the Danish farmers could get the additional quotas mostly for free, whereas the Dutch ones had to buy the extra quantities.

In the UK, milk quotas were allocated on an individual basis but managed on a national level through the marketing board areas. Surpluses of individual farmers were partly or fully offset by under supply by others. Quotas can be traded freely and this has resulted in 8% of the national quota being leased and 2% being sold. Quotas are now of significant economic value and have become an important entry barrier.

Evidence on structural changes in UK dairying as a result of quotas is present. There is a continuing migration of quotas away from farms with better ways of using their land to those whose qualities do not allow alternatives

Generally spoken, there are similarities between the property rights in fisheries and in agriculture with respect to high prices of individual rights and acceleration of concentration tendencies. The fishery sector could consider some solutions implemented in the dairy sector, such as facilities for newcomers in the Danish dairy industry and fiscal allowances for valuable production rights in case of succession in the Dutch agriculture industry.

Structural implications of property rights

The implementation of a decommissioning scheme in 1987 has had a major influence on the structure of the Danish fleet, rather than the property rights mentioned before. The fleet has decreased by 20% in the period 1986-1992 as a result of this scheme and also caused by the bad stock situation for some of the main target species. Especially the fishery for cod has declined with major consequences for some of the trawler segments. The relatively old Danish seiners fleet has taken benefit from the decommissioning scheme.

The structure of the Dutch cutter fishery has changed importantly since 1983, whereby private property rights has had the following impacts:

- stimulation of decommissioning since the leavers could get extra proceeds by selling their ITQ;
- prevention of fleet expansion;
- creation of barriers for newcomers;
- more aging of the fleet, since investments in rights may have partly absorbed the depreciations for new vessels;
- quota hopping, induced by lower prices of rights abroad;
- some concentration of rights i.e. ITQs. The rights are less concentrated compared with the situation in New Zealand and Iceland. For example, the 3% owners of the largest ITQs possess 47% of the national quota in Iceland (1994) whereas this percentage is 17.5% for the Dutch flatfish quota.

The UK experience seems to indicate property rights having relatively little influence so far on structural developments. The relevant factors appear to be technical changes, profitability and decommissioning payments. The loss of distant waters made much of the fleet of 70's redundant and subsequent investment, encouraged by government, changed both the structure and location of the fleet. The inshore sector grew and the location moved northwards in the UK.

One feature which does derive from UK property rights has been the reflagging of foreign vessels by acquiring UK licences.

Another feature related to property rights has been the increasing strength of POs. The share of important quotas managed by POs and number of vessels in membership has increased significantly.

Effects of property rights at enterprise level

In Denmark profitability of the vessels is, on average, at break-even level for most fleet segments. Profits use to fluctuate highly over the years and losses are no exception, especially for the trawler segments. The economic situation seems to be more positive for the Danish seiners .

Limitations in the fisheries for human consumption have resulted in more investments in industrial fisheries. The restrictions on extension of capacity add an extra cost to consider in investment decisions. These extra costs cause uncertainties for individual enterprises since future fishing possibilities are not secured enough by fishing rights.

Investments in Dutch flatfish ITQs can only contribute to profits through a marginal approach, when only variable costs are matched against the extra proceeds from the purchased ITQ. A net present value analysis points out that the pay-back period for these investments exceeded eight years in 1994. Thus, it is in the interest of the investors in ITQs that the individual rights remain beyond 2002, the year of a possible review of the CFP.

The gross margin (proceed minus the variable costs) resulting from the ITQ investments is too low to cover also the fixed costs of the vessel. The present (capitalized) value of a large, a 'full' ITQ would only be some 40% of its purchase cost for the 1994 situation. This means that newcomers cannot enter the fishery, for example by taking over a second handed vessel with all the rights. On the other hand, this shows that existing ITQ holders have a strong preference to continue their enterprise. They could indeed sell their right and realize a much higher proceed than they would get from future fishing activities.

Purchased property rights are an important intangible asset on the balance sheet of Dutch enterprises in the cutter sector. Financing from banks has facilitated these purchases, whereby the ITQs may serve as a collateral for a loan. Property rights in fishing mostly meet the requirements for recognition as an intangible asset following the International Accounting Standards Committee (IASC). Therefore it is preferable to follow the IASC recommendations and to include costs for the rights (depreciation and interests) in profit calculations.

Valuable rights may hamper the transfer of the enterprise to the next generation or to other family-members. Fiscal allowances, in force for production rights in the Dutch agriculture, have partly been applied for fishery enterprises. However, barriers for succession still may remain and 'the transitional gains trap' (Parzival Copes, 1992) occurs in the Dutch fishery.

In the UK the most obvious effects of property rights at the enterprise level are in increasing the costs to new entrants and those vessel owners expanding their businesses. The returns from such investments would appear to be negative at the current cost of licences. Equally property rights have introduced a new economic dimension for those wishing to leave the industry. Besides of the vessel their assets now include the value of the licence. This value has increased over the years as tighter licencing rules and decommissioning have improved the balance between capacity and catches available. There is now an higher opportunity cost of remaining in the industry.

Succession of ownership has become more difficult. It contains more complicated effects where families or other close knit groups are involved.

Factors influencing property rights regimes

Comparison of different property rights systems could raise the question: which is the best system? F.T. Christy has a rather clear answer to this question. In his paper to the 8th Biennial Conference of the Institute of Fisheries Economics and Trade [1] he states in this respect: 'The

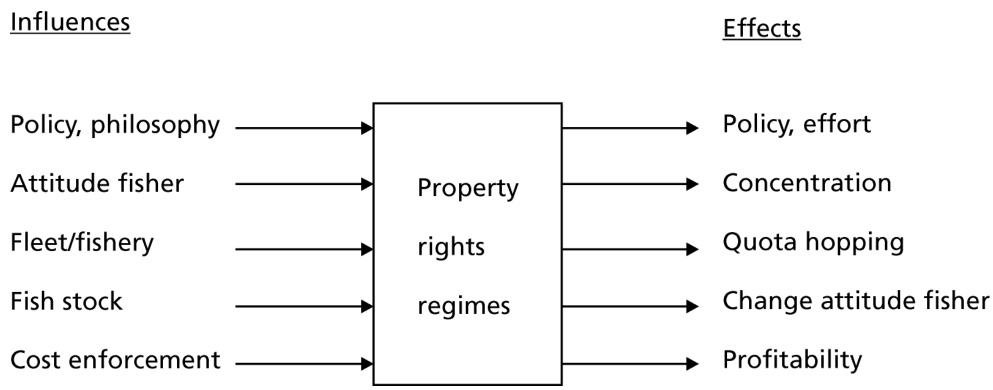
[1] 'Paradigms lost: the death rattle of open access and the advent of property rights regimes in fisheries', Francis T.Christy, prepared for the 8th Biennal Conference of the Institute of Fisheries Economics and Trade, Marrakesh, Morocco, 1-4 July 1996.

transition to property rights regimes in fisheries is occurring with a speed which, I think, is not fully appreciated. The process is inexorable' (p.3). The command and control system of fisheries management is a paradigm lost in his view and property rights regimes represent the paradigm gained. In this respect he quotes Hannesson (in press, 1996): 'The state would become redundant as a management authority and its only role would be the ultimate upholding of the rule of law and the honouring of contracts'.

From this point of view the Danish command and control system is more or less obsolete and would or should move to the Dutch regime of property rights. This regime meets rather well the 'new paradigm' of Christy since ITQs have been established for all quota species, managed by user groups and the government aims to reduce its role. However, the views expressed in Christy's paper can be critized by arguing that property rights systems cannot be considered in itself. There are several influencing factors which explain why the regulations are as they are:

- the policy of the government, that may not be in favour of property rights, as is the case in Denmark and also in countries like France and in Belgium. Policy makers may have the opinion that they lose too much control over the fishery when they allocate rights to individuals or organisations;
- the attitude of the fishermen, e.g. they may opposed against individual property rights because they fear concentration of rights amongst bigger enterprises;
- the fleet structure and the fishery, which may be more or less suited for the implementation of property rights such as ITQs. In this respect the rather homogeneous Dutch beam trawl fleet is less complicated than the more diversified British and Danish fishery;
- the situation of the fish stocks, e.g. a stock in danger that needs a severe reduction in TACs, compared with the open access circumstances, may have other consequences for limiting measures and rights than 'healthy' fish stocks.

Hence, property right regimes are to a certain extent dependant variables, beyond economic efficiency. On the other hand they may induce new developments when they have been implemented. Examples are quota hopping and concentration tendencies that have been accelerated because of trade in rights. Figure 1 intends to illustrate that property rights regimes cannot be considered in isolation but rather as a part of a comprehensive policy.



Selected influences on and effects of property rights in the fishing industry

Statements resulting from the EU FAIR study on property rights in the fishery sector

- A useful definition for property rights in fishing is (Bromley, 1991): 'Property is not an object such as land but is rather a right or group of rights to a benefit stream that is only as secure as the duty of all others to respect the conditions that protect that stream';
- this definition means for fisheries that the right can be defined in terms of harvest and not in terms of stocks;
- '..the duty of all others..' is a key element in this definition and this makes clear that the security of the rights importantly depends on enforcement;
- property rights in fishing are frequently confused with individual rights. It is however necessary to distinguish between three types of rights: state-, common- and private or individual property rights;
- fisheries management should firstly define the property rights and make a choice between these three types of rights, or combinations of them, and from this basic choice necessary measures can be taken;
- the coming review of the Common Fisheries Policy should be considered more from the viewpoint of property rights;
- management systems tend to evolve unavoidably into the direction of individual property rights regimes from the moment that a limitation has changed into a right and vested interests have arisen;
- non-transferable rights that create exclusivity will be transferred gradually;
- property rights do not have advantages in itself, but they have to be considered against a background of preferences and attitudes of policy makers and fishermen;
- an important advantage of ITQs mentioned in literature, stimulating management behaviour of fishermen, is supported by evidence in the Dutch beam trawl sector;
- under a regime of individual property rights effective protection of the rights leads to proper protection of the fish stock.

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