INCENTIVE BASED FISHERIES REGULATION SYSTEMS: THE CASE STUDY OF THE CANTABRIAN ANCHOVY FISHERY*

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Abstract

A partir de un enfoque de optimización dinámica se comparan los distintos sistemas indirectos de regulación de pesquerías basados en la creación de incentivos: a) impuestos piguvianos (sobre inputs, sobre output) b) mecanismos basados en la asignación de derechos de propiedad (cuotas/licencias individuales transferibles) de distinto horizonte temporal (transitorio, multianual o perpetuo). Se calculan los impuestos óptimos, así como los precios de las cuotas individuales que incentivarían a los pescadores a la adopción de la asignación socialmente deseable y se analiza la sensibilidad de dichos impuestos/precios ante cambios en los parámetros del modelo de referencia. Se pone especial atención en la aplicabilidad de los sistemas descritos, para lo cual se introduce el caso de estudio de la pesquería de la anchoa europea de la división VIII, en la que están implicadas las flotas de bajura de la cornisa Cantábrica, especialmente las de Galicia, Asturias, Cantabria y País Vasco.

KEY WORDS: Quotas, Licenses, Individual Transferable Quotas, Individual Transferable Licenses, Anchovy Fishery, Implementation.

1. INTRODUCTION

The main reason of divergence between the open access and socially optimal allocation is Munro and Scott's (1985) Class I form of rent dissipation. The lack of property rights in the fish stock incentives fishermen not to consider the impact of his

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own activities on other fishermen and on the future availability of fish. Consequently too few fish are left in the sea to contribute to future biomass growth, which implies higher harvesting costs in the future.

The obvious policy prescription to face economic inefficiency derived from mentioned Class1 problem is a Total Allowable Catch (TAC). In theory a TAC should permit a sustainable resource rent to emerge, although in practice, the race to fish push the firms to unprofitable over-investment in fishing effort and to an excess of capacity of the fleet, the well-known consequences of a Class II form of rent dissipation.

The theoretical solution to face the excessive fishing effort should then be a restricted access policy, which basically consists in directly limiting the amount of effort by only permitting the minimum effort needed to take the TAC. In practice, the real issue when implementing a limited entry program concerns which of the many inputs to restrict, because if the underlying fishing technology permits the substitution of unrestricted inputs for the restricted ones, then the intentions of the regulation will be subverted and the Class II problem accelerated.

In recent years there has been a clear movement toward property rights based fisheries management systems around the world. Special attention has been paid to the advantages and disadvantages of individual quotas (IQ). With no need to race for the fish, operators presumably would be induced to use only the most economically efficient capital and labour input configurations. Moreover, letting the IQ to be transferable quota rights would be in the long term consolidated in the hands of the most efficient operators. However, ITQ systems, besides requiring a previous TAC, seem not to improve the problem of bycatches and require a solid method of monitoring and enforcement (specially difficult when a large number of landing ports and small market distribution chain are). Besides, the determination of he initial allocation of quotas may be difficult and controversial and the regional impact on small fishing communities irreversible.

Any case, all the mentioned regulation systems have supported the theoretical proof of their efficiency, but most of them failed when being applied and implemented to real fisheries. Often similar management plans give sensible different results when they are applied to the same species depending on the socio-economic context of the area of application. Thus, the empirical validation of a management system requires also thinking about its applicability to specific fisheries industries, which undoubtedly implies learning from case studies.

In this sense, this paper analyses different regulation systems (i.e. quotas/licenses) and places the sight in the case study of the VIII division European anchovy fishery. First of all, the prices of the quotas /licenses conducting to economically efficient allocation will be calculated within an optimisation framework, to go on with the discussion on the probability of success of the mentioned mechanisms when hypothetically implemented to the mentioned fishery.

2. THE THEORETICAL BACKGROUND

The fiction of the *sole owner* (Scott, 1955), is usually adopted to address the desired socially optimal economic allocation in a fishery. Being able to be imagined as either a corporation (Towsend, 1998), a regulatory agency or a benevolent social planner that *owns complete rights* to the exploitation of a given fish population (Clark, 1990), the sole owner is assumed to face a restricted discounted profit maximisation problem in an infinite time horizon and determine the so called economically optimal stock (S*), fishing effort[1] (E*) and catch levels (Y*), internalising the shadow value of the resource (μ) as well as the interactions or negative externalities among agents.

Let $Y_i(t)$, $E_i(t)$ and S(t) respectively denote the catches, fishing effort of the representative fisherman i (control variable) and the stock in period t (state variable). P and r are assumed exogenous parameters expressing the price per tonne of fish harvested and the social discount rate, while $c_i(E)$ is the opportunity cost of effort[2]. $f(S(t),E_i(t))$ and g(S(t)) are well behaved[3] production and population growth functions. Then, under several simplifying assumptions (i.e. infinite demand elasticity, homogeneous technology of the N operating fishermen and absence of crowding externalities) the current value Hamiltonian (H_c) associated to the sole owner's profit maximisation problem is:

$$H_c = \left(p\sum_{j=1}^{N} f(S(t),E_i(t)) - c_i(E_i(t)) \right) + \mu\left(g(S(t)) - \sum_{j=1}^{N} f(S(t),E_i(t)) \right) \qquad (1)$$

Based on the first order conditions associated to (1) (FOC1)=$\{[\partial H_c/\partial E_i=0(i=1,...,N)];[-\partial H_c/\partial S=\partial\mu/\partial t-r\mu];[\partial H_c/\partial\mu=0^4]\}$ resulted from

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[1] Theoretically *fishing effort* is a composite measure, a micro production function $E=f(z_1, z_2,\ldots,z_n)$ of different z_i production factors including capital and labours used in harvesting.
[2] Marginal factor cost $\partial c_c/\partial E_i=c_c' > 0$
[3] The function, g(S(t)), is assumed to be twice differentiable with a maximum value, commonly referred to as the maximum sustainable yield (MSY). $F(S(t),E_i(t)$ is a quasiconcave macroproduction function of stock and effort.
[4] When dealing with *infinite horizon autonomous* problems, the transversally condition required to determine the boundary condition is replaced by the assumption that the optimal solution approaches the steady state situation.

applying the maximum principle, $E^*= \sum E^*_i$, S^*, $Y^*=\sum Y^*_i$ and μ are obtained. Thus, the economic rule for the efficient allocation of effort contained in the maximum equation[5] implies that the value of the marginal productivity of effort for the representative fisherman (f_{Ei}) discounted by the shadow current price (μ) is equal to the marginal cost of effort (c'_i) [i.e. $(p-\mu)\, f_{Ei} = c'_i$ (2)]. Given an initial inefficient allocation [E(0), S(0), Y(0)] $\neq$ [E*, S*, Y*], the optimal policy will be to choose an effort level that drives stock to S* as fast as possible *(bang.bang control*), including the unpopular closure of the fishery whenever S(0) < S*.

In the other institutional extreme (i.e. in *open access*), characterized by the inexistence or badly defined property rights, no restriction is placed on fishermen wishing to enter the fishing grounds: there is no limit on the amount of fish that may be caught by individual vessels and any effective control over the fishing effort. Consequently the main agent to be borne in mind is the individual fisherman, who following a *"first come first served"* strategy tries to obtain his individual maximum profits exploiting the resource purely competitively, that is to say, taking no notice of the effect that their own harvesting might have on the future resource stock, or putting in another words, acting as if the shadow price of the resource was z□□□ (Clark, 1980, 1990). The current value Hamiltonian for fisherman i can be expressed as follows:

$$H_{c_i} = \left(pf(S(t),E_i(t)) - c_i(E_i(t))\right) + \lambda_i\left(g(S(t)) - \sum_{j=1}^{N} f(S(t),E_i(t))\right) \qquad (3)$$

where, (λ_i) represents the individual marginal valuation of the stock. Considering a pure open access scenario $\lambda_I=0$, the individually optimal allocation entails that each of the fishermen will adopt the rule [$pf_{Ei} = c'_i$] (4)[6].

When comparing the open access aggregate effort level ($E_{OA}=\sum E_{OAi}$) stock (S_{OA}), and open access aggregate profits ($\Pi_{OA}=\sum\Pi_{Oai}$) with the respective optimal values it is straightforward to concluded that $E_{OA}>E^*$, $S_{OA}< S^*$ and $0 \leq \Pi_{OA}< \Pi^*$. In the short term (with a sufficient small number of participants (N), the open access individual profits can be positive, and consequently, with no barriers to entry, it may incentive new entrants. As a result, N will not stop increasing until the *economic rent* of the fishery is completely dissipated. Thus, in the long term, the steady state open access will be

[5] $\partial H_c/\partial E_i=0$ (i=1,...,N)

[6] If following Boyce (1992) $\lambda_I>0$, necessarily $0<\lambda_i\leq\mu$, holds. In this case (4) is substituted by $(p-\lambda_i)f_{Ei} = c_i'$.

resumed in equation [PY/E = c(E)] (4'), indicating that the value of average productivity of effort equals its cost.

To face the consequences of Class 1 rent dissipation and help ensure sustainability of the resource and meet socio-economic objectives, fisheries managers regulate the fisheries, either with direct regulation methods based on the limitation of the fishing activity [i.e. input restrictions (on fishing days, fishing capacity, etc.) and/or output restrictions (total allowable catches (TAC)] or with indirect methods trying to affect the incentives on behaviours (i.e. taxes (on inputs or outputs) and rights (quotas, licenses)). In this paper we are referring exclusively to systems in the second group.

Starting in an open access setting, Piguvian taxes convert a situation of rent dissipation into one of rent capture. If the tax rate is set correctly, either on the harvest itself (T_Y) or on fishing effort (T_E), the implicit rental value of the fishery resource will be maximised. Even if agents act purely competitively (λ_I=0), taxes really involve either an increase of costs or a decrease on the net price of the harvest, which generates microeconomic incentives to decrease the individual effort and catch levels, finally conducting the fishery to the optimal allocation (E*,S*,Y*). The respective individual current value hamiltonians under a Piguvian tax on harvest or equivalently under a Piguvian tax on effort are:

$$H_{c_i} = (p - T_y) f(S(t), E_i(t)) - c_i(E_i(t)) + \lambda_i \left(g(S(t)) - \Sigma_{j=1}^{N} f(S(t), E_i(t)) \right) \quad (5)$$

$$H_{c_i} = pf(S(t), E_i(t)) - (c_i(E_i(t)) + T_E) E_i(t) + \lambda_i \left(g(S(t)) - \Sigma_{j=1}^{N} f(S(t), E_i(t)) \right) \quad (6)$$

T_Y can be directly calculated equalling the maximum equation related to (5) [i.e. [(p-T□) f_{Ei} = c'_i] with (2). Analogously, equalling the maximum equation associated to (6) [$pf_{Ei} = c'_i + T_E$] with (2) T_E is obtained. Thus, the corrective taxes on catches and/or effort that would conduct the fishery to the optimal (i.e sole owner's) allocation are:

$$T_Y = \mu \quad (7)$$ [7]

$$T_E = \mu f_{E_i} \quad (8)$$ [8]

However, with no more restriction on entry, the existence of positive profits may incentive new entrants even in presence of taxes. That is why the marginal productivity of effort in the maximum equations associated to (5) and (6) is often substituted by the

[7] If the individual marginal valuation of the stock is consider λ_i>0, then the value of the corrective taxes on catches would be T_Y=μ–λ

[8] If the individual marginal valuation of the stock is consider λ_i>0, then the value of the corrective taxes on effort would be T_E= (μ–λ_i)f_{Ei}

average productivity of fishing effort (Y/E), letting that way the calculation of the long run corrective taxes on catches ($T_Y(\pi=0)$ and on effort ($T_E(\pi=0)$.

$$T_Y(\Pi=0) = p - \frac{f_{E_i}[p-\mu]}{(Y_i / E_i)} \qquad (7)'$$

$$T_E(\Pi=0) = p(Y_i / E_i) - f_{E_i}[p-\mu] \qquad (8)'$$

In an ITQ-system the management authorities take care of the stock externality through deciding the optimal total allowable catches (TAC) in each period. Assume that an amount of quota $q_i(0)$ is issued gratis in an initial period (0), while the remainder, until reaching the TAC is placed in a efficient quota market at an uniform price (s_T). Let $Z_i(t)$ the amount of net quota acquired by fisherman i at t, while $\overline{q_i}$ represents the maximum quantity fisherman i is allow to harvest[9]. Thus, the current value Hamiltonian for the representative fisherman i is:

$$H_{c_i} = pf(S(t),E_i(t)) - c_i(E_i(t) - s_T Z_i(t) + \lambda_i\left(g(S(t)) - \sum_{j=1}^{N} f(S(t),E_i(t))\right) + \gamma\left(q_i(0) + Z_i(t) - \overline{q_i}\right) \qquad (9)$$

Starting from the first order conditions associated to (9) (FOC9)={[$\partial H_c/\partial E_i=0$]; [$H_c/\partial Z_i=s_T+\gamma$]; [$\partial H_c/\partial S=\partial\lambda/\partial t-r\lambda$]; [$\partial H_c/\partial\lambda=0$] [$\partial H_c/\partial\gamma=0$]}, comparing the maximum condition in FOC9 [i.e. [($p-\lambda$) f_{Ei} = c'_i] with the corresponding to the sole owner's problem [i.e. [($p-\mu$) f_{Ei} = c] it is straightforward to derive that if $s_T=\mu$ the ITQ system would conduct the fishery to a efficient allocation.

Equivalently, assume that under an ITL-system the authorities issue gratis $x_i(0)$ effort units, while the remainder, until reaching the total allowable effort (TAE) is placed in a competitive market at a price l_T. Let n_i the number of effort units acquired by fisherman i and $\overline{x_i}$ his maximum effort level exercisable. Thus, the current value Hamiltonian is and the respective first order conditions are:

$$H_{c_i} = pf(S(t),E_i(t)) - c_i(E_i(t) - l_T n_i(t) + \lambda_i\left(g(S(t)) - \sum_{j=1}^{N} f(S(t),E_i(t))\right) + \gamma\left(x_i(0) + n_i(t) - \overline{x_i}\right) \qquad (10)$$

(FOC10)={[$\partial H_c/\partial E_i=0$]; [$H_c/\partial n_i=l_T+\gamma$]; [$\partial H_c/\partial S=\partial\lambda/\partial t-r\lambda$]; [$\partial H_c/\partial\lambda=0$] [$\partial H_c/\partial\gamma=0$]}. Putting side by side the maximum condition in FOC10 [i.e. [(pf_{Ei} = c'_i+ l_T] with the one associated to the sole owner problem and [i.e. [($p-\mu$) f_{Ei} = c'_i] it is straightforward to derive that if $l_T=\mu f_{Ei}$ the ITL system would conduct the fishery to an efficient allocation.

If instead of transitory the rights (either ITQs or ITLs) are permanent each of the representative fishermen should decide the amount of profit maximising quota to

[9] $TAC=Y^*=\sum_j q_i(0)+\sum_j Z_i(0)=\sum_j \overline{q_i}$

acquired ($Z_i(t)$) at each moment. The regulator, after issuing gratis an amount of permanent catch quota ($q_i(0)$ (effort quota ($x_i(0)$)) places the remainder (until reaching the (TAC)) *at each moment t* in a quota market at a price $s_{Pi}(t)$ (or $l_{Pi}(t)$. Let $q_i(t) = q_i(0) + \int_0^t Z_i(\varepsilon)d\varepsilon$ (or equivalently $x_i(t) = x_i(0) + \int_0^t Z_i(\varepsilon)d\varepsilon$) represent the total catch (or effort) quota hold by i, which also determines his maximum quantity of fishing effort for period t[10]. Assuming that ITQs (ITLs) are dividable and transferable in a competitive quota market, the current value Hamiltonian associated for the representative fisherman i is:

$$H_{c_i} = pq_i(t) - c_i(t)E_i(t) - s_{Pi}(t)Z_i(t) + \gamma Z_i(t) \tag{12}$$

Starting from (FOC12) =[$\partial H_c/\partial Z_i = 0$] [$\partial H_c/\partial q_i = r\gamma - \partial\gamma/\partial t = 0$] and rearranging the maximum condition under the assumption of the equality of the marginal value of the quota (MV_q) and its average value (AV_q),[11]; solving the differential equation (13), the optimal price of the perpetual catch (effort) quotas emitted for an infinite period (n=∞) ($s_{Pi}(0)$ ($l_{Pi}(0)$ or for finite number of years ($s_{Pi}(0)_n$ ($s_{Pi}(0)_n$ can be obtained.

$$\dot{s}_i(t) - rs_i(t) = -\left[p - c_i\frac{\partial E_i}{\partial q_i}\right] \tag{13}$$

$$s_{Pi}(0)_{n=\infty} = \frac{1}{\sum_i q_i}\sum_{i=1}^{J}\int_0^{\infty}(pq_i - w_iE_i)e^{-rt}dt = \frac{pY_i - w_iE_i}{Yr_i} \tag{14}$$

$$s_{Pi}(0)_n = \frac{1}{\sum_i q_i}\sum_{i=1}^{J}\int_0^{n}(pq_i - w_iE_i)e^{-rt}dt = \frac{pq_i - w_iE_i}{Y_i}\left[\frac{1-e^{-rn}}{r}\right] \tag{15}$$

$$l_{Pi}(0)_{n=\infty} = \frac{1}{\sum_i n_i}\sum_{i=1}^{J}\int_0^{\infty}(pq_i - w_iE_i)e^{-rt}dt = \frac{pY_i - w_iE_i}{E_ir} \tag{16}$$

$$l_{Pi}(0)_n = \frac{1}{\sum_i n_i}\sum_{i=1}^{J}\int_0^{n}(pY_i - w_iE_i)e^{-rt}dt = \frac{pq_i - w_iE_i}{E_i}\left[\frac{1-e^{-rn}}{r}\right] \tag{17}$$

Taxes and allocated transferable vessel quotas would in theory serve to correct the misallocation of resources resulting from the common-property externality. They are mathematically equivalent in their effect on effort use, and hence on economic efficiency. Moreover, under the important assumption of transferability, the initial distribution of quotas is irrelevant, as far as achieving an economically efficient equilibrium is concerned, since the quota market will lead to an efficient redistribution of quotas (Clark, 1980, 1990). Besides, taxes or quotas on catch, respectively, are

10 $Y_i = f(E_i, S) = q_i(t) \Rightarrow E_i = g(q_i, S)$

11 $MVq = \left[p - w_i\frac{\partial E_i}{\partial q_i}\right] = AVq = \left[\frac{pq_i - w_iE_i}{q_i}\right]$

equivalent to taxes or quotas on fishing effort, which follows trivially from the assumed direct relationship between catch and effort implicit in the production function. Hence, since [$T_y = s_T = \mu$] & [$T_E = l_T = \mu$□$_E$] it follows that $T_E = T_Y$ □$_E$.

The theoretical equivalence of taxes and allocated quotas, while perhaps of considerable economic interest should not be taken too literally. For, in practice, quotas obviously provide a direct control over catches, and hence over the state of the fish stock, whereas taxes act only indirectly. The precise relationship between tax rate and total catch rate would depend on the price of fish, the cost of fishing effort, and in general on he behavioural responses of the fishermen, all of which are subjected to serious imprecision and uncertainty.

Despite the described equivalency of allocated individual quotas and taxes in terms of efficiency, their distributional implications are radically opposite. Whereas taxing implies extracting the economic rent from the sector to the public purse, in the case of allocated quotas, as the raising rent is capitalised in the market price of the quotas, it is therefore retain in the industry. Although that political considerations will continue to require that a major share of any economic benefits from the resource accrue to the fishing industry, rather than directly to the public purse, the development of ITQ fisheries has rekindled interest in the idea of imposing special taxes (i.e. resource rentals) on the sector. But in contrast to the efficiency-enhancing aspects of a corrective tax under open access condition, the main objective of taxation under an ITQ system is the transfer of wealth from owners of quota to the government (Johnson, 1995). The implicit idea surrounding resource rentals is that optimum allocation could be theorically achieved via any combination of quota and taxes; In this cases the maximum equation becomes $(p\text{-}T_Y\text{-}s_T)f_E = c'(E)$[12]. From the distributional pint of view, this allows the government to divide the economic rents of the fishery in any desired proportion between fishermen and public revenue.

3. THE CASE STUDY OF THE EUROPEAN ANCHOVY

The development of the bio-economic model for the anchovy fishery is based upon the econometric estimation of the population[13] and production functions[14] (Table

[12] $T_Y + s_T = \mu$

[13] The OLS regression results indicate that both coefficients are correct signed and significant at the 5% level. The adjusted R^2 and F are satisfactory. Durbin Watson and Box Pierce tests did not detect autocorrelation while Jarque-Bera test let us accept the normality of the residuals. The R^2 of the auxiliary regressions is practically 0, so we considered that the degree of multicolinearity is acceptable. The functional form thereby obtained is

1) from time series data (1966-95) of biomass (Uriarte, 1995), catch and effort (ICES) (Table 1) and the calculation of the ratio c/p[15]. See del Valle et al. (1998, 2001) for further details.

-TABLE 1- Estimations of the population growth and production functions

CUSHING population growth function ln(S(t+1)+Y(t)) = lna+bLn(t)							
lna = 4.28** (7.69)	b= 0.645** (6,82)	–	*F* 46.55	$\overline{R}^2$ 0.61	DB 2.10	BP 7.46	JB 0.83
COBB DOUGLAS production function lnY(t) = lnq + αLnS(t)) + βE(t)							
lq = -1.1397 (-0.9265)	α=0.68226** (7.11)	β=0.6656** (3.12)	*F* 52.68	$\overline{R}^2$ 0.78	DW 1.91	BP 12.22	JB 2.28

Own elaboration (del Valle et al. (2001).
Data source: Uriarte (1995), ICES.
** Significant at 5%

The bio-economic diagnosis resulted from the simulation of the anchovy fishery under maximum (sole owner) and zero profit scenarios (open access) is not very optimistic: The evolution of the fishery is a long way from reaching economically optimal solutions, being very close to an open access allocation. The stock was found to be well below what would be considered the optimal interval, the number of vessels is extremely high, and catch levels show signs of being unsustainable in the long term. Moreover, the results question the validity of the rules limiting its access and

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$g(S(t)=72.2549S(t)^{0.645} - S(t)$, which implies a maximum sustainable yield (MSY) of 27,571.7 tonnes, a required biomass for MSY of 50,095 and a maximum carrying capacity (MCC) of172,479 tonnes.

[14] The lack of information of alternative proxies in order to form an index for the fishing effort (E) obliged us to chose the number of vessels to represent (E). Despite the simplification, it is worth mentioning that in schooling fisheries (like anchovy) searching for schools is of predominant importance and accordingly, in such fisheries the number of participating vessels may be an appropriate measure of effort (Bjorndal, 1987). Besides, in spite that two different vessel types participate in the fishery (purse seines and pelagic trawlers), the few degrees of freedom linked with the short length of the time series (1986-1995) and the short quota share of the pelagic fleet made it not possible to obtain different production functions for each of the sub-fleets. Therefore, using a procedure similar to that of Sathiendrakumar and Tisdell (1987), we opted for an equivalence criterion, finally resulting one pelagic vessel to be equivalent of 1.59 purse seine (del Valle, 1998). The model, estimated by OLS, fit the data fairly well. All the variables are significant at the 5% level, the signs are correct, and according to F and adjusted R^2 it seems jointly valid. Durbin Watson and Box Pierce test do not detect autocorrelation, while Jarque-Bera test let us accept the normality of the residuals. The R^2 of the auxiliary regressions is practically 0, so we consider that the degree of multicolinearity is acceptable. Thus, the estimated standardised production function is $Y(t) = f(S(t), E(t)) = 0.319915S(t)^{0.68226} E(t)^{0.66562}$.

[15] Cost and price data to derive the ratio c/p were collected from "Anuario Estadístico del Sector Agroalimentario" (1986-1995) and Caill (1995). As data were on an annual basis (disregarding the fact that many fisheries work seasonally) we calculated the proportion of total costs attributable to anchovy fishing, considering the time devoted to it. The derived c/p values range between 40 and 100 and the average value is 70. Finally, a discount rate from 0,05 to 0,1 is considered acceptable for the purposes of the study.

exploitation (del Valle et a. 2001)[16]. Table 2 includes a summary of reference values for the optimal stock (S*), number of vessels (E*) and TAC*. The mean (1966-95) period values of stock (S^-), number of vessels (E^-), and catches (Y^-) have been also included.

[16] Since the mid-eighties there is a precautionary TAC of 33,000 tonnes. By virtue of the historic rights and the principle of relative stability 90% of the TAC goes to purse seine Spanish fleet (250 vessels), while the rest 10% is shared by the french pelagic (150 vessels) and the testimonial French purse seine fleet. The optimal bio-economic TAC proposal was between 18,000 and 26,000 tonnes, while the recommended number of licenses was no higher than 222.

-TABLE 2- Optimum (S*, E*, TAC*) and mean real reference values (S^{-}, E^{-}, Y^{-})

	S*	E*	TAC*	S^{-}	E^{-}	Y^{-}
BASE CASE*	[98,000 - 100,000]	[131 - 140]	[21,000]	50,898	402*	29,798
BASE INTERVAL**	[78,000 - 115,000]	[90 - 222]	[18,000, 26,000]	–	–	–

* c/p = 70; 0.05 <r<0.1
*c/p=[40, 100]. 0.05<r<0.1
* 412 standardised vessels = 386 real vessels.
Source: del Valle et al. (2001)

Different alternatives to the reinforcement of the present regulation system (i.e. a lower TAC and a real restricted entry programme maybe complemented by a financial aid for the withdrawal of remaining vessels and workforce) could also care about to improve the situation of the fishery. In the case of an additional input limitation programme to restrain overcapacity, the results of the cross sectional production analysis in del Valle et al. (2003)[17] suggests that fishermen could counteract a limitation on one input with increments in other inputs, although the high proportion of vessels with the Allen Elasticity of Substitution (AES) and Morishima Elasticity of Substitution (MES) ranged between [-1,1] indicates limited substitution possibilities between the inputs making up fishing effort. The detected asymmetry for MES suggests that an input limitation program based on the reduction in the boat days would be more efficient than an equivalent one limiting the gross registered tonnes (GRT) or the horsepower (HP).

Deeper changes could be also taken into account to conduct the fishery towards bio-economic optimality paths. Among them, in this paper we are considering corrective taxes on catches and effort as well as individual transferable quotas and licenses. Following the behavioural models presented in section 2, the optimal quota and license prices will be calculated and the real implementation of the system discussed.

Table 3 summarises the optimal corrective pigouvian taxes per tonne harvested and the optimal pigouvian taxes on fishing effort for c/p and r reference values in Table 2. In order to compare the resulting corrective taxes on catches and effort, two alternative scenarios have been included: the short run one implying positive after tax net profits (equations 7 and 8) and the long run solution characterised by zero net profits

[17] A primal formulation was used to estimate a translog production function at the vessels level in order to study the substitution possibilities among inputs making upthe empirically validated fishing effort aggregate input.

(equations 7' and 8'). Graph 1 illustrates the optimal zero-net profits taxes on harvest ($T_Y(\pi=0)$), the optimal positive-net profits taxes on harvest (T_Y), the optimal zero-net profits taxes on effort ($T_E(\pi=0)$) and the optimal positive-net profits taxes on effort (T_E) for different c/p and r values.

-TABLE 3- Illustrative optimum reference corrective pigouvian taxes

	T_Y	T_E	$T_Y(\pi=0)$	$T_E(\pi=0)$
BASE CASE*	[979 - 1,049]	[113,038- 101,847]	[1,655 - 1,702]	[258,443 -275,320]
REALISTIC INTERVAL**	[716 - 1,503]	[94,140 - 120,558]	[740 - 2,004]	[111,582 - 307,715]

* c/p = 70; p=3000; $0.05 < r < 0.1$
**c/p=[40, 100]. $0.05<r<0.1$, p=[1,500, 3000]
$T_Y=\mu$; $T_Y=\mu\ f_E$; $T_y(\pi=0) = p-\beta(p-\mu)$; $T_E(\pi=0) = (Y/E)\ [p-\beta(p-\mu)]$

In order to analyse the sensibility of the piguvian taxes to different parameters in the model, for simplicity and concordance with axes in Graph 1 taxes relative to anchovy prices will be considered. Note that for a Cobb Douglas technology[18] the next equivalencies hold:

$$T_y/p(\pi=0) = 1-\beta(1-\mu/p) \quad (18)$$

$$T_E/p(\pi=0) = (Y/E)\ [T_y/p(\pi=0)] \quad (19)$$

$$T_y/p = \mu/p \quad (20)$$

$$T_E/p= \beta(Y/E)\ [T_y/p] \quad (21)$$

$$T_y/p(\pi=0) = 1-\beta(1- (T_y/p)) \quad (22)$$

$$T_E/p(\pi=0) = (Y/E)\ (1-\beta) + T_E/p \quad (23)$$

It is easy to show that both the optimal zero net profit and positive net profit taxes per tonne harvested relative to anchovy prices ($T_y/p(\pi=0)$) (T_y/p) decrease as the ratio c/p and/or r increases. Given that [$\Delta c/p \rightarrow \nabla\mu/p$] and/or [$\Delta r \rightarrow \nabla\mu/p$], it directly implicates a) $\partial(T_y/p(\pi=0))/\partial(c/p) < 0$, b) $\partial(T_y/p)/\ \partial(c/p) < 0$, c) $\partial(T_y/p(\pi=0))/\ \partial r < 0$, d) $\partial(T_y/p)/\partial r < 0$. Besides, since $\mu/p<1$, it can concluded that $T_y/p(\pi=0) > T_y/p$.

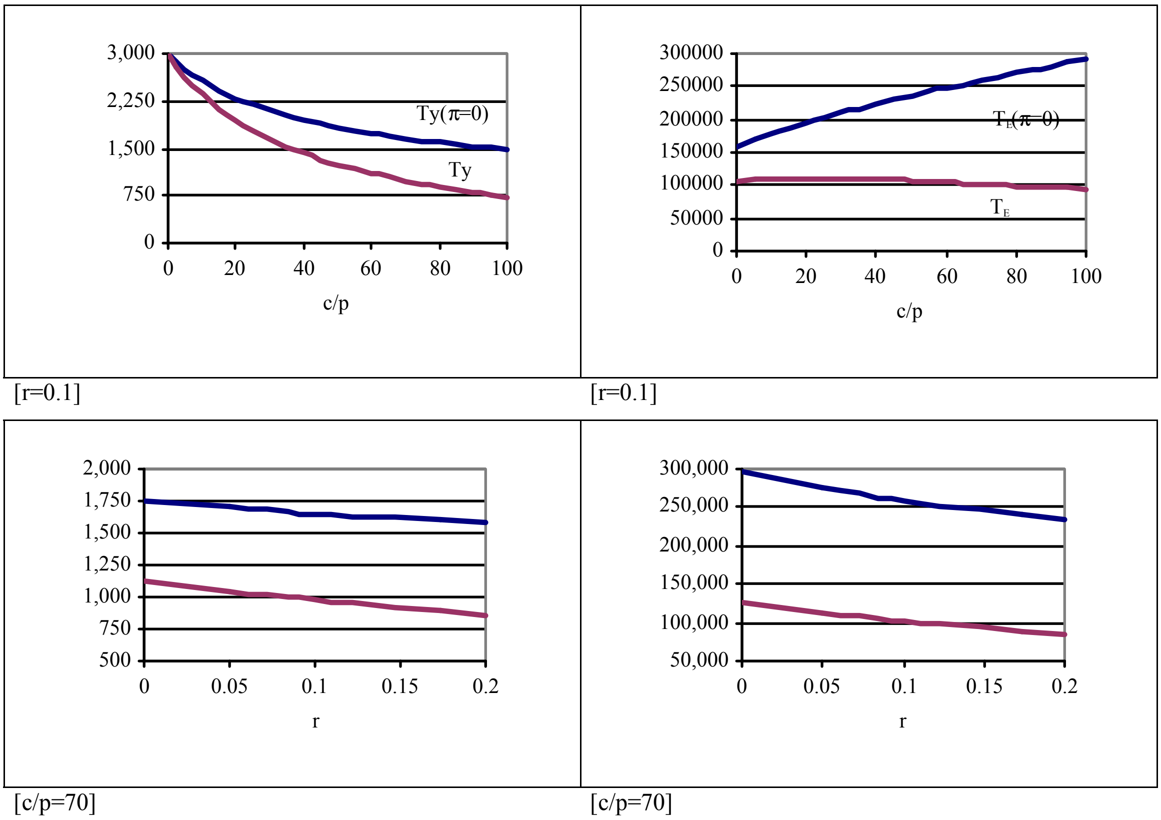
However, as the values of optimal zero net profit ($T_E/p(\pi=0)$) and positive net profit taxes per effort relative to anchovy prices (T_E/p) as well as depending on the current shadow value of the resource relative to price (μ/p) are also related to the

[18] Note that the average productivity of fishing effort (Y/E) is equal to β□□□□□□marginal productivity of effort. (βf_E) Since $0<\beta<1 \Rightarrow (Y/E) > f_E$

average productivity of fishing effort (Y/E); increases in the ratio c/p impulse two opposite-signed effects: [$\Delta c/p \rightarrow$ 1. $\nabla\mu/p$ 2. $\Delta(Y/E)$]. Taking into account (21) and (23) [$\partial(T_E/p(\pi{=}0))/\ \partial(c/p) > 0$] $\forall$ c/p $\in[0,100]$, while T_E/p reaches a maximum value when c/p = 20 and is decreasing for c/p>20[19]. For another side, wince $\Delta r \rightarrow [\nabla\mu/p\ \&\ \nabla(Y/E)]$, then $\partial T_E/p(\pi{=}0)/\ \partial r < 0$ and $\partial(T_E/p)/\ \partial r < 0$. Additionally, as $0<\beta<1$, $T_E/p(\pi{=}0) > T_E/p$ holds.

-GRAPH 1-

Sensibility analysis of optimal harvest taxes T_Y (π=0), T_Y and effort taxes $T_E(\pi{=}0)$, T_E



The asymmetric nature of the partial derivatives of taxes on catches and taxes on effort as a result of $\Delta c/p$ needs further explanation. First, it is worth remembering that as the fishing effort is represented by the number of operating vessels, an optimal tax per unit of effort would be theoretically equivalent to the optimal price of a licence, which changing the fishermen incentives would conduct the fishery to the socially optimum allocation (S*, NB*, Y*) and to the increase of the economic rent. Precisely, each of the

[19] Note that in the case of $T_E/p(\pi{=}0)$ when $\Delta c/p$ the positive effect of increasing average productivity appears twice, mitigating the negative one {$\uparrow$ (Y/E) (1-β) + β(Y/E) $\uparrow\mu/p\downarrow$ } while in the case of T_E/p, the increase in the average productivity is compensated with the decrease of the shadow price {β(Y/E) $\uparrow\mu/p\downarrow$ }

after tax-surveying vessels would have to pay in form or tax or licence part or total of its individualised profits. As a result of the marginal stock effect (Bjorndal, 1987) the reduction of the profitability associated with Δc/p, induces some fishermen to abandon the activity (∇E) originating ΔS and therefore average productivity increases (ΔY/P). Given that the remaining vessels will be able to earn an increasing average profit despite Δc/p, the optimal prices of the licences are positively related to Δc/p. Equivalently, if the fishermen are obliged to pay an optimal tax or quota per tonne harvested the long run steady state optimum allocation (S*,NB*,Y*) will be reach, generating the appearance of a positive economic rent. Thus, the authorities would extract in the form of taxes the individualised profit per tonne of fish caught. As a result of Δc/p the per tonne profit per tonne harvested decreases and consequently the fishermen would have to pay smaller taxes per tonne fish.

-TABLE 4- Illustrative optimum reference prices for permanent ITQ and ITL

			$s_p(0)_n$			$lp(0)_n$		
	s_T	l_T	$s_p(0)_5$	$s_p(0)_{15}$	$s_p(0)_{25}$	$l_p(0)_5$	$l_p(0)_{15}$	$l_p(0)_{25}$
BASE CASE*	979 1,049	113,038 101,847	6,513 7,529	12,860 17,959	15,194 24,286	1,017,145 1.218,010	2,008,261 2,905,358	2,372,873 4,391,050
REALISTIC INTERVAL**	716 1,503	94,140 120,558	2,912 8,865	5,749 21,146	6,793 28,895	309,320 1,361,322	866,842 3,247,204	1,024,221 2,681,603

* c/p = 70; p=3000; 0.05 <r<0.1

**c/p=[40, 100]. 0.05<r<0.1, p=[1,500, 3000]

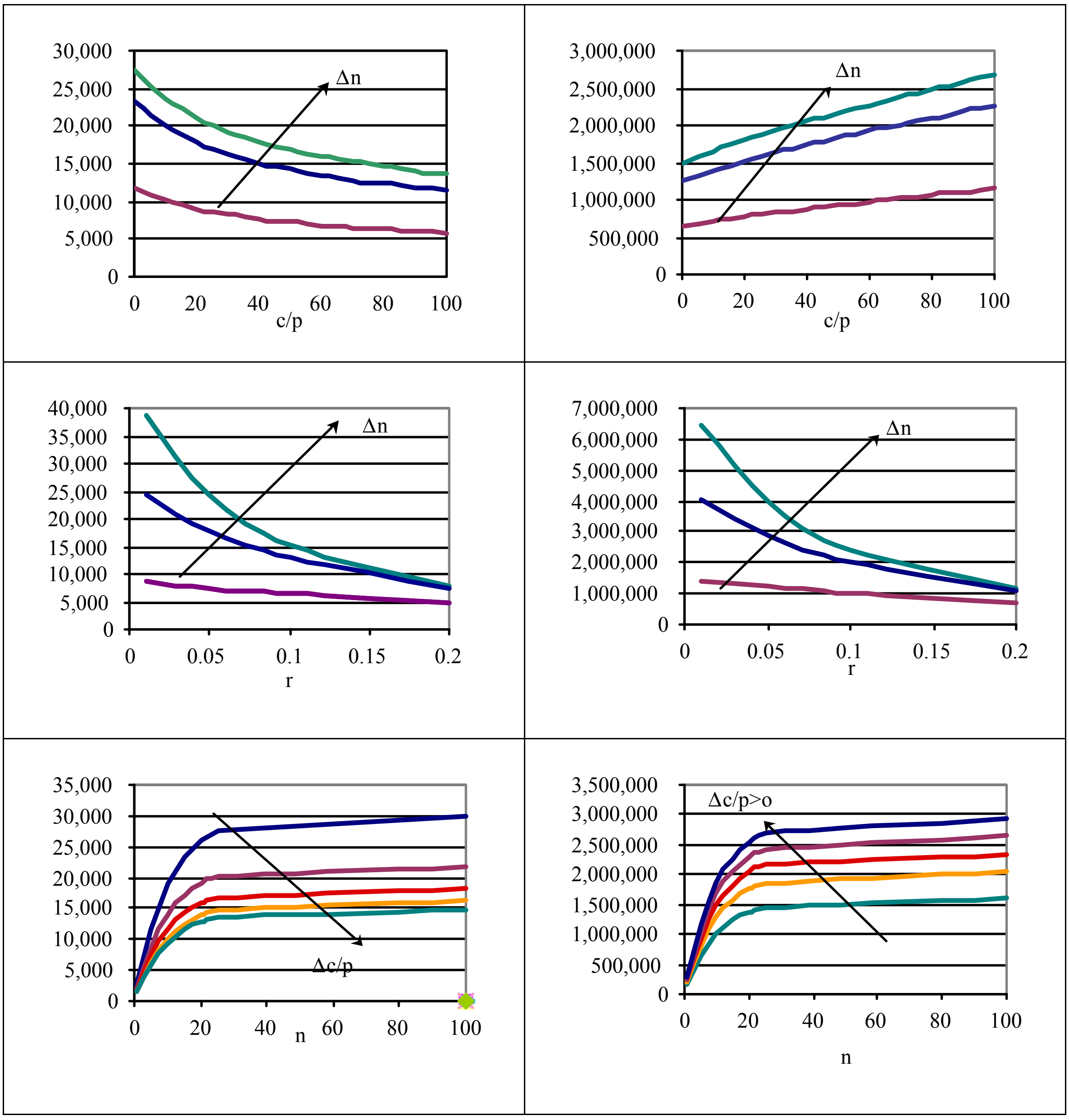
sY=μ; lY=μ fE $s_{Pi}(0)_n = \frac{pq_i - w_i E_i}{Y_i r}\left[1 - e^{-rn}\right]$ $l_{Pi}(0)_n = \frac{pq_i - w_i E_i}{E_i r}\left[1 - e^{-rn}\right]$

Table 4 summarises the optimal prices of the permanent ITQs ($s_p(0)_n$) and ITLs ($l_p(0)_n$) considering different emission periods (n=5, n=15, n=25). Graph 3 shows the sensibility analysis of $s_p(0)_n$) and $l_p(0)_n$ as a result of changes in the c/p ratio, the discount rate (r) and the quota emission period (n). The sensibility analysis of the mentioned parameters is not far away from the results obtained for pigouvian taxes and transitory quotas and licenses. Note that the optimal prices for individual permanent quotas and licenses are respectively the product of the profit per tonne harvested (Π_Y) and the term A [A= (1-e^{-rn}/r)] and the profit per effort unit (Π_E) A. Since $\partial\Pi_Y/ \partial c/p < 0$ and the term A is invariant to changes in c/p ratio, necessarily $\Rightarrow \partial s_p(0)_n / \partial c/p < 0$. Just in the opposite sense, given that $\partial\Pi_E/ \partial c/p > 0$, then $\Rightarrow \partial l_p(0)_n / \partial c/p > 0$. Besides, as a result of two same directional effects [i.e. 1. $\partial\Pi_Y/ \partial r< 0$ and 2. $\partial A/ \partial r < 0$; and equivalently 1. $\partial\Pi_E/ \partial r < 0$ 2.$\partial A/ \partial r < 0$] it is concluded that both prices decrease whenever r increases. Finally, since ∂A/∂n > 0, the fishermen would have to pay higher optimal prices per tonne harvested and also for effort units, the longer the emission period is.

These quota prices should be carefully interpreted. It is not easy to involve fishermen and fishing firms in a deeply changed fishery governing system, asking them to pay high prices for quotas or licences. Besides, quota and prices are subject to change conditions depending variations of prices, cost and productivity. Nevertheless, the calculated optimal prices introduce a long-term rationalisation criterion.

-GRAPH 2-

Comparative static of ITQ prices ($s(0)_n$) and ITL prices



[r=0.1]	[r=0.1]

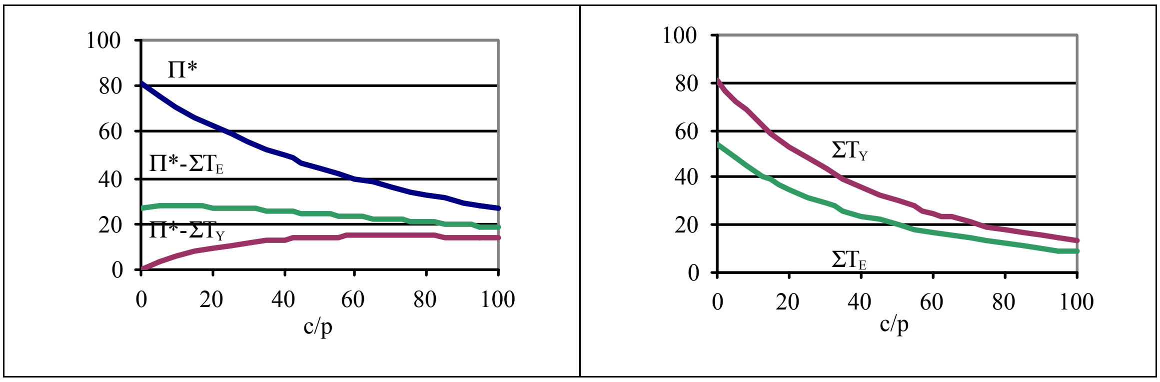
4. SOME CONIDERATIONS ON IMPLEMENTATION OF QUOTA AND LICENSING SYSTEMS ON ANCHOVY FISHERY

The explicit relationship between catch and effort [i.e. Y_i=f(S,E_i)] involves that effort taxes are certainly merely transformations of catch taxes. However, even though both mechanism are constructed to allow the optimal steady state long run allocation (S*,E*,Y*) they present two important peculiarities. For one side, taxing catches or taxing fishing effort has different distributional effects referring to net after tax profits obtainable in the anchovy fishery (Graph 2). Concretely under an effort taxing system, the after tax net profits are higher (and consequently rent capture smaller) than under a harvest taxing system. For another side, at a practical level, catches would be much more easily gauged than is effort. Consequently, catch taxes would normally be expected to provide more accurate control over the fishery than effort taxes.

Despite taxes (on catch or on fishing effort) would in theory serve to correct the misallocation of resources resulting from the stock externality externality, evidence points that taxes have not been the regulatory instrument of choice in fisheries. Comparing with allocated vessel quotas, taxation does not benefit fishers, who have political clout in lobbying against taxation. Thus, taxing seems not to be a workable alternative to the present regulation of the VIII division European anchovy fishery.

-GRAPH 3-

Rent capture T_Y (π=0), T_Y and effort taxes T_E(π=0), T_E



Although theoretically right-based systems (i.e. ITQs, ITLs) eliminate the incentives for racing in investments, conducting the fishery towards economic efficiency, it is broadly accepted that they cannot be considered in isolation. There are several political and socio cultural factors (such us the policy of the government, the attitude of the fishermen, the feet structure, the fishery situation of the stocks, the costs of enforcement) influencing their effectiveness (Davidse et al., 1999). Thus, it's convenient to remember that the potential virtual ties of right-based systems could fail when being implemented to real fisheries, as besides economics, it has, important political and social consequences.

One of the most controversial points when designing ITQ systems seems to be initial allocation of quota rights[20]. If the principle of stability restriction is to be maintained, initial allocation of anchovy quotas should be distributed between the involved states according to the present quota shares of the TAC. Afterwards different criteria[21] could be used to distribute the quotas: either to individual fishermen or to fishermen groups (i.e. Cofradías, or Fishermen Organisations), which a priori seems to be more in concordance with the socio-cultural background of the concerned areas.

The next step is to affront the dimension of quota transferability[22], the time horizon of the quotas[23], and the legal questions surrounding the issues of taxation, depreciation and the use of quotas as collateral loans.[24] Anchovy is a short lives species, and consequently the time horizon of the quotas should be limited to a maximum compatible with the rationalisation of capital inversions, avoiding as well the potential unconstitutional situation that could be created by perpetual allocation of quotas. Moreover, although limiting transferability is positively related to efficiency losses, conflict minimisation and potential negative distributional effects would require limiting it, al least to the fleets currently participating in the fishery.

Special attention deserves the monitoring plan design. If fishermen can contravene regulations with impunity, the potential advantages of the system are lost.

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[20] Often the historical rights have been used to arrange initial allocation; being thus penalized those with new investment projects or those with more productive fleets but less historical rights. Another discussion element is the rate to pay for each quota. Several ways could be taken: from being freely distributed or being charged by a quantity depending on average prices, costs, effort and stock abundance, to being auctioned (Veteman et al, 2002). Of course different options would have different distributional results.

[21] Egalitarian, according to the dimensions of the vessels (Norway case, see Arland and Bjorndal, 2002), related to historic catches (Icelandic case, see Eythorsson (2000).

[22] From non-transferability, to limiting transferability only among fishermen of the same country or fishing gear)

[23] Ttransitory or permanent.

[24] For example in Iceland the quotas are taxed like private capital, and since 1998 quota zares cannot depreciated. The collateral problem has been solved by mutual agreements between banks and and boat owners to ensure that quota zares and vessels could not be separated without consulting the bank. See Eythorsson (2000).for more details related to legal quoestions of ITQs.

Experiences of ITQs in different countries (Canada, Icelandic, Australia and New Zeland) recommend including random surveillance and dockside monitoring, data entry and analysis, and investigation of reports of non-compliance of quota regulations. One of the mayor hurdles faces is the large number of fishing vessels and ports where anchovy is landed. Besides, an institution and its composition should be arranged to implement the effective controls. Choosing a neutral agency or committee may be rather difficult, but experiences in European Union fisheries suggest that delegating control tasks to European member states is not very effective.

Last but not least, economic, biological, social and regional potential effect should be tried being anticipated. As well as the effect on profits or the effects on biomass and harvests, the ones concerning to industry concentration and changing fleet structure ought to be analysed taking into account a multi-species approach and the interactions among different kind of fleets (i.e. artisan, industrial). ITQs tend to concentrate capital, production and commercial chain. This concentration could push to eliminate previously existing fishing activity, which might carry important changes in geographical distribution of the industry and employment related to fishing. The distributional effects between vessel owners and crew ought to be also consider, especially the potential effects on the wages as a result of unexpected-sided effects like contract fishing[25].

Regarding to ITLs, one of the most remarkable advantages is that licensing lets the regulatory agency a dynamical evaluation of the stock and the stabilisation of a changing TAC in accordance to the real abundance of the resource, which is very interesting for short lives species, like anchovy, subject to great oscillations in recruitment. Once again the initial allocation of licences should be arranged. In this his case the relative stability restriction would be more difficult and controversial to implement, because the present regulation of the anchovy fishery is based on TAC and state quotas. Consequently, an equivalence criterion between quota share and fleet share should be accorded.

It is also remarkable that controlling and monitoring should not be very difficult, despite the great dimension of the initial fleet and the number of the landing ports implied in the fishery. However, if licenses do not go accompanied by complementary measures, they can stimulate the race of investments reported specially with inputs that

[25] i.e. fishing for others, which means that a vessel owner short of quota enters a leasing contract with a quota owner, which could bring speculative leasing transactions that could reduce wages.

are not stipulated in the license contract. Consequently, it would be necessary to design other appropriate harmonizing measures to face the inefficient consequences of the race to fish. Besides, capacity increment associated with technological advances should be avoided and contemplated in the evolution of the number of licenses.

Whatever the regulation system to be adopted it is important to take in mind the degree of implication each of the systems allows. The best method can fail if the institutional framework does not give chance to the operators to understand and to involve themselves with the global objectives of the management system.

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