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QUOTA AND LICENSING SYSTEMS IN THE VIII DIVISION EUROPEAN ANCHOVY[1]

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Abstract

In this paper quota and license based management of VIII division European anchovy fishery is analysed under an optimisation framework and complete information assumption. The optimal prices of the catch or tax quotas, license fees or taxes on effort and the prices of perpetual transferable quotas (ITQ) and perpetual transferable licenses (ITL) are also calculated and the comparative static illustrated. Finally some considerations on the applicability and implementation of the introduced regulation methods are presented.

KEY WORDS: Individual Transferable Quotas, Individual Transferable Licenses, Piguvian catch and effort taxes, Anchovy Fishery, Implementation.

1. 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[2] (E*) and catch levels (Y*), internalising the shadow value of the resource (μ) as well as the interactions or negative externalities among agents.

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[2] 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.

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[3]. $f(S(t),E_i(t))$ and $g(S(t))$ are well behaved[4] 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)={[$\partial H_c/\partial E_i=0 (i=1,...,N)$];[$-\partial H_c/\partial S=\partial\mu/\partial t-r\mu$];[$\partial H_c/\partial\mu=0$[5]]} resulted from 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[6] 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 <u>open access</u>), 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

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[3] Marginal factor cost $\partial c_c/\partial E_i=c_c' > 0$

[4] 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.

[5] 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.

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

in another words, acting as if the shadow price of the resource was zero (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 λ_I=0, the individually optimal allocation entails that each of the fishermen will adopt the rule [$pf_{Ei} = c'_i$] (4)[7].

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 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:

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

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

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

T_Y can be directly calculated equalling the maximum equation related to (5) [i.e. [(p-T_Y) 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:

$$T_Y = \mu \quad (7)$$ [8]

$$T_E = \mu f_{E_i} \quad (8)$$ [9]

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

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

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

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[10]. Thus, the current value Hamiltonian for the representative fisherman i is:

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

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-λ_i) f_{Ei} = c'_i] with the corresponding to the sole owner's

[8] 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=$\mu-\lambda$

[9] 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= ($\mu-\lambda_i$)f_{Ei}

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

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 $\bar{x}_i$ his maximum effort level exercisable. Thus, the current value Hamiltonian is and the respective first order conditions are:

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

(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 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[11]. Assuming that ITQs (ITLs) are dividable and transferable in a competitive quota market, the current value Hamiltonian associated for the representative fisherman i is:

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

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),[12]; solving the differential equation (13), the optimal price of the perpetual catch (effort) quotas emitted for an infinite period ($n=\infty$) ($s_{Pi}(0)$ ($l_{Pi}(0)$ or for finite number of years $(s_{Pi}(0)_n$ $(s_{Pi}(0)_n$ can be obtained.

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[11] $Y_i = f(E_i,S) = q_i(t) \Rightarrow E_i = g(q_i,S)$

[12] $MVq = \left[p - w_i\dfrac{\partial E_i}{\partial q_i}\right] = AVq = \left[\dfrac{pq_i - w_i E_i}{q_i}\right]$

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

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

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

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

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

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 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 $[T_y = s_T = \mu]$ & $[T_E = l_T = \mu f_E]$ it follows that $T_E = T_Y f_E$.

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 $(p-T_Y-s_T)f_E = c'(E)$[13]. 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.

2. 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[14] and production functions[15] (Table 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[16]. See del Valle et al. (1998, 2001) for further details.

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[13] $T_Y+s_T = \mu$

[14] 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 $g(S(t)=72.2549S(t)^{0.645} - S(t)$, 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.

[15] 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 $Y(t) = f(S(t), E(t)) = 0.319915S(t)^{0.68226} E(t)^{0.66562}$.

[16] 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.

-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 exploitation (del Valle et a. 2001)[17]. 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.

-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

[17] 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.

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)[18] 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 (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]
$T_Y=\mu$; $T_Y=\mu\ f_E$; $T_y(\pi=0) = p-\beta(p-\mu)$; $T_E(\pi=0) = (Y/E)\ [p-\beta(p-\mu)]$

[18] 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.

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[19] 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 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[20]. 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.

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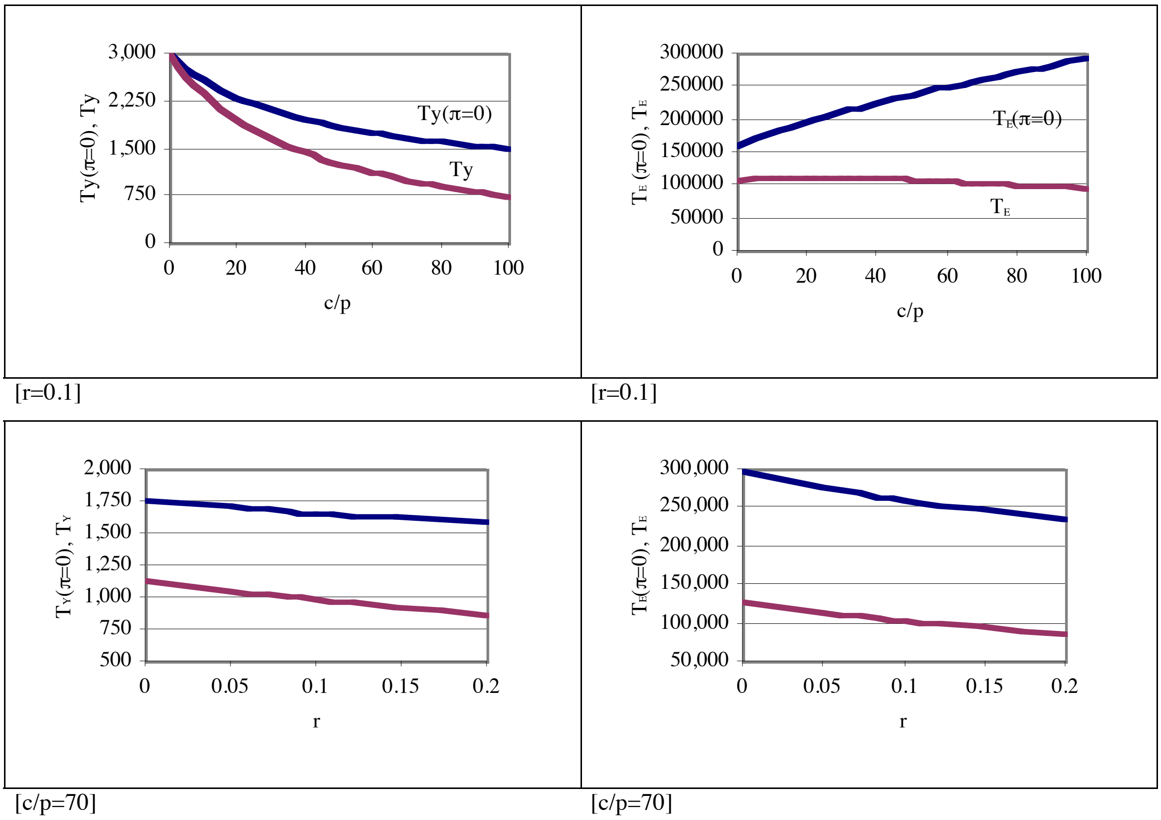
[19] Note that the average productivity of fishing effort (Y/E) is equal to β per the marginal productivity of effort. (βf_E) Since $0<\beta<1 \Rightarrow (Y/E) > f_E$

[20] 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) $\uparrow\mu/p\downarrow$ }

-GRAPH 1-

Sensibility analysis of optimal harvest taxes T_Y (π=0), T_Y and effort taxes T_E(π=0), T_E



The asymmetric nature of the partial derivatives of taxes on catches and taxes on effort as a result of Δc/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 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]

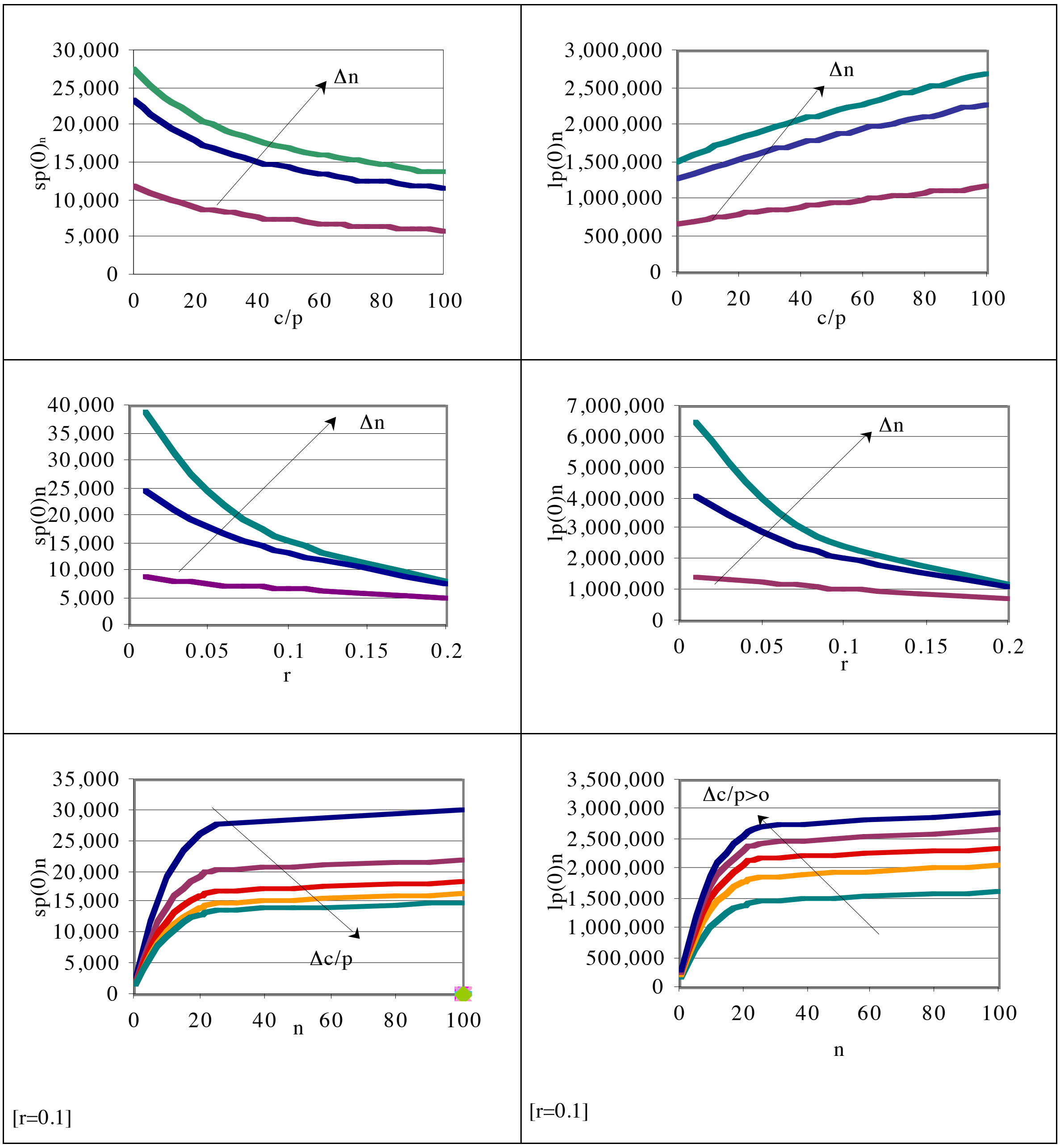
sY=$_\mu$; lY=$_\mu$ fE $s_{Pi}(0)_n = \frac{pq_i - w_i E_i}{Y_i r}\left[1 - e^{-rn}\right]$ $l_{Pi}(0)_n = \frac{pq_i - w_i E_i}{E_i r}\left[1 - e^{-rn}\right]$

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= $(1\text{-}e^{-rn}/r)$] 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 $\partial A / \partial n > 0$, 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



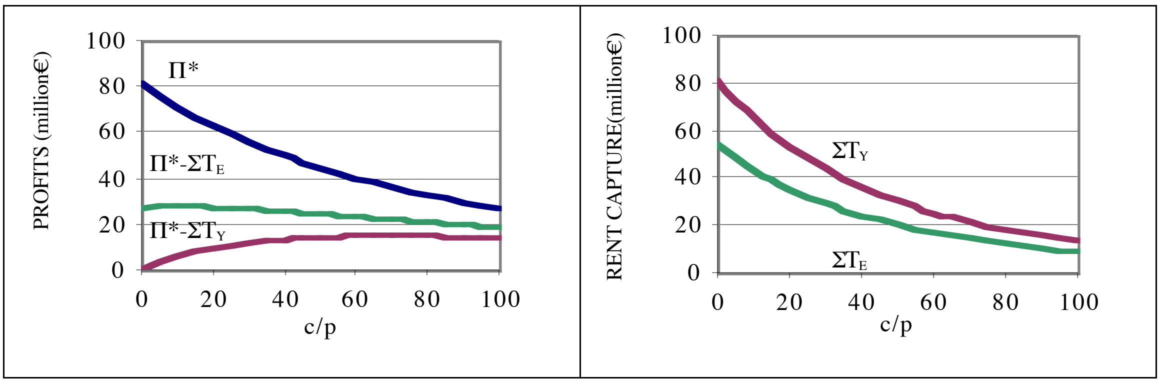
4. SOME CONSIDERATIONS ON IMPLEMENTATION OF QUOTA AND LICENSING SYSTEMS ON ANCHOVY FISHERY

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 common-property 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



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Although theoretically right-based systems (i.e. ITQs, ITLs) eliminate the incentives for racing in investments, conducting the fishery towards economic efficiency, 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. 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.

Let us nowcentre in ITQs. One of the most controversial points when designing ITQ systems seems to be initial allocation of quota rights. 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. Of course different options would have different distributional results.

Under the principle of stability restriction, initial allocation of anchovy quotas should be distributed between the involved states according to the present quota shares of the TAC. Afterwards different criteria could be used to distribute the quota to individual fishermen (egalitarian, discrimination by the dimension of the vessel, related to historical catches of he vessel, etc). The next step is to affront the dimension of quota transferability: from been non-transferable, to limiting transferability only among fishermen of the same country or fishing gear. Once again one decision or other would probably imply important regional impact on the coastal areas.

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

In the case of licensing, the regulatory agency should establish a TAC based on stock evaluation and afterwards emit the number of licenses compatible with the TAC. Once again the initial allocation of licences should be arranged. In t his case the relative stability restriction is more controversial, because the present regulation of the anchovy fishery is based on quotas. Consequently, an equivalence criterion should be accorded. In relation of the rate to pay for each of the licenses, it could be freely distributed or being charged by a quantity depending on average prices, costs, effort and stock abundance, or even auctioned. Any case special withdrawal programs should be considered. The dimension of the license transferability should also be decided (not transferability, limit transferability only among fishermen of the same country or fishing gear, etc). Of course the decision would probably imply important regional impact on the coastal areas.

As well as the fishermen the regulatory agency could as well take part in the market, buying and selling titles. This way the agency has an essential instrument to intervene and to regulate the license market and thus it makes the necessary adjustments about the number of licenses available in the market. The stock variations have reflection through TAC in the number of optimal licenses. When there is not equilibrium in the market, the optimal number of licenses is reached in the market with regulator intervention

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. In this sense, licensing allows affording regulation problems tailored as case studies, with special insight to environmental context and with particular answer to specificities of each case. So it promotes a regulation made to measure of necessities.

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. As it was mentioned in the case of regulation by quotas, an institution and its composition should be arranged to implement the effective controls, instead of delegating control tasks to the states.

However, if licenses do not go accompanied by complementary measures, they can stimulate the race of investments reported specially with inputs that are not stipulated in the license contract. Moreover, firms could still race to catch the greater amount of fish in the smaller time, because they know that TAC size is the upper limit to catch between all participants firms in the fishery. 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.

From economic efficiency criterion view, it's necessary to indicate that this method appears like one that can be in some aspects less effective than those based on exclusive stock rights negotiated in a market of titles. Licenses regulation system gives preferences to several optimising criterion (economic, social, political, etc). Its objective does not consist to guarantee the efficiency exclusively in the economic sense, although letting the licences to be transferable efficiency gains could be expected in the long term.

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.

Distributional effects of ITQs, in terms of income distribution between owner and crew and also between different fleets as well as the vulnerability of fisheries communities, have been in the centre of the debate.

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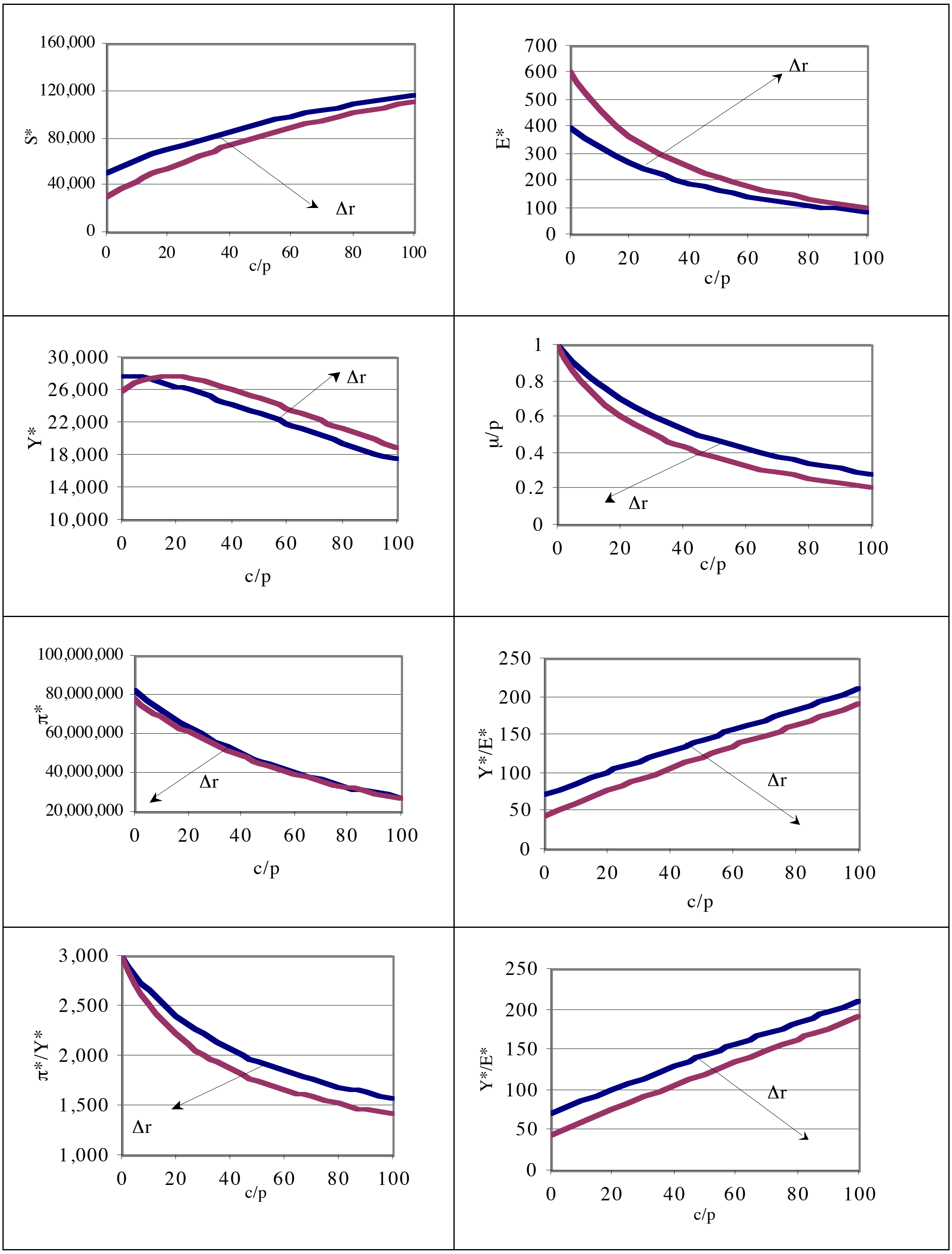
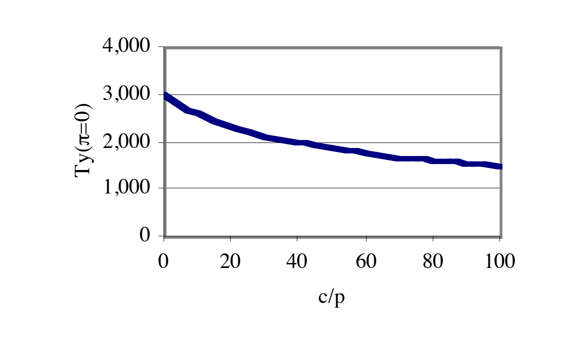
-GRAPH 3-

Sensibility analysis of the efficient allocation

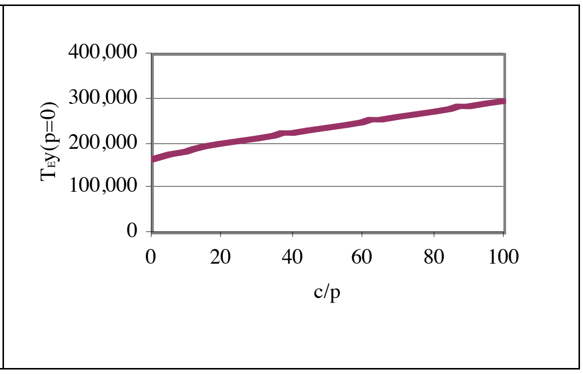


-GRAPH 1-

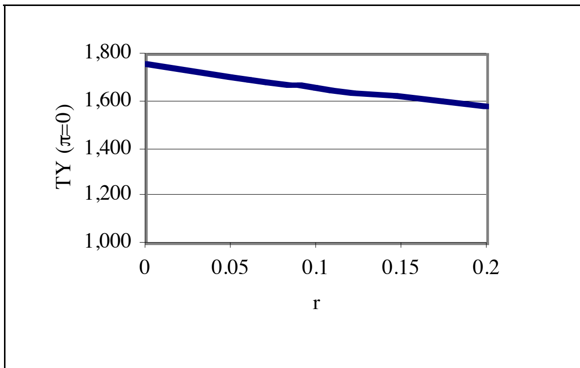
Sensibility analysis of optimal harvest taxes (T_Y (π=0)) and effort taxes (T_E(π=0))



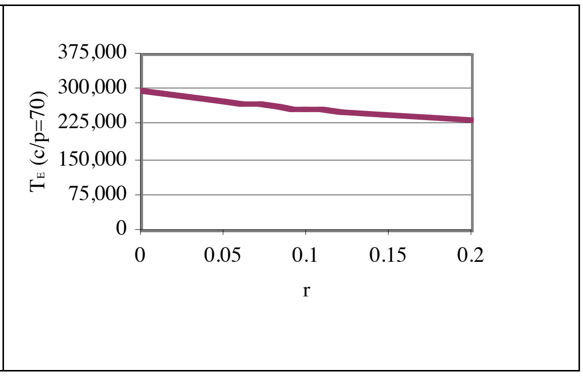
[r=0.1]



[r=0.1]



[c/p=70]



[c/p=70]

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

$T_y(\pi=0) = p-\beta(p-\mu)$

$\Delta c/p \quad \nabla\mu/p \quad \Delta 1-\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow \partial(T_y/p(\pi=0))/\, \partial(c/p) < 0$

$\Delta r \quad \nabla\mu/p \quad \Delta 1-\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow \partial(T_y/p(\pi=0))/\, \partial r < 0$

2) $T_E/p(\pi=0) = (Y/E)\, [1-\beta(1-\mu/p)] =(Y/E)\, T_y/p(\pi=0)$

$T_E(\pi=0) = (Y/E)\, [p-\beta(p-\mu)] =(Y/E)\, T_y(\pi=0)$

$\Delta c/p \quad \Delta\Delta(Y/E) \quad \nabla\mu/p \quad \Delta 1-\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow$ $\partial(T_E/p(\pi=0))/\, \partial(c/p) > 0$

$\Delta r \quad \nabla(Y/E) \quad \nabla\mu/p \quad \Delta 1-\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow$ $\partial(T_E/p(\pi=0))/\, \partial r < 0$

3) $T_y/p = \mu/p$

$\Delta c/p \quad \nabla\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow \partial(T_y/p)/\, \partial(c/p) < 0$

$\Delta r \quad \nabla\mu/p \quad \nabla\, T_y/p$ which implies $\Rightarrow \partial(T_y/p/\, \partial r < 0$

4) $T_E/p = \beta(Y/E)\, \mu/p = \beta(Y/E)\, T_y/p$

$\Delta c/p \quad \Delta(Y/E) \quad \nabla\mu/p \quad \Delta\, T_E/p \quad (c/p<20) \quad \nabla\, T_E/p \quad (c/p>20)$

which implies $\Rightarrow \partial(T_E/p)/\, \partial(c/p) > 0\ (c/p <20)$

$\Rightarrow \partial(T_E/p)/\, \partial(c/p) < 0\ (c/p >20)$

which implies $\Rightarrow \partial(T_E/p/\, \partial r < 0$

$\Delta r \quad \nabla\, (Y/E) \quad \nabla\mu/p\ \nabla\, T_E/p$ which implies $\Rightarrow \partial(T_E/p/\, \partial r < 0$

5) $T_y/p(\pi=0) = 1-\beta(1-\mu/p) > T_y/p = \mu/p$

$1-\beta > \mu/p - \beta\mu/p) = \mu/p\ (1-\beta)$ since $\mu/p<1 \Rightarrow T_y/p(\pi=0) > T_y/p$

6) $T_E/p(\pi=0) = (Y/E)\, [1-\beta(1-\mu/p)] > T_E/p = \beta(Y/E)\, \mu/p$

$(Y/E)- \beta(Y/E)+ \beta(Y/E)\mu/p > \beta(Y/E)\, \mu/p$ since $(Y/E)(1-\beta)$ is >0 due to $0<\beta<1$

$Y= qS^{\alpha}E^{\beta}$

$\beta(Y/E) = f_E/\beta$. Since $0<\beta<1 \Rightarrow (Y/E) > f_E$

$f_E = MP_E = \partial Y/\partial E = q\beta S^{\alpha}E^{\beta-1} = \beta Y/E = \beta AP_E$

$AP_E = Y/E = qS^{\alpha}E^{\beta} / E = qS^{\alpha}E^{\beta-1}$

It is worth mentioning that there are important similarities between licences or taxes on effort for one side, and quotas or taxes on catches for another. All of them have the same theoretical consequences.

Although if the tax rate is set correctly (either on fishing effort or on the harvest itself) theoretically the implicit rental value of the fishery resource will be maximised, the corrective taxes have not been the regulatory instrument of choice. One obvious reason is that taxation does not benefit fishers, and they have political clout in lobbying against taxation.

Individual transferable quotas (ITQs) are a form of property rights that can solve the inefficiencies of open access fisheries and generate a Pareto optimal market solution in a fishery.

The fisheries management authorities are assumed to take care of the stock externality through deciding the optimal TAC (Y*) and optimal stock level (S*) in each moment of time. These values are found solving the social planner's problem above. To maximize the above expression firm i maximises its profits condition

Now, instead of a corrective tax, consider the assignment of ITQs. The purpose of the ITQ is to limit entry and increase the rents generated in the fishery. Of course, allocating ITQs is the same of distributing wealth, so disagreement and conflict can be expected. But once the assignment process has been completed, the ITQs provide a means for managing the fishery. If those engaged in the fishery were to maximise aggregate net returns under the ITQ system, the optimal harvest rate would seemly be the same as that selected under the corrective tax scheme. Given that the two systems for regulating the fishery yield the same outcome, at least theoretically, it is tempting to conclude that the taxing authority could proceed to tax away the market value of quota altering resource use. If correct, a tax on quota value would be neutral, causing no distortions in the primary market.

The dynamic problem of a price-taking fisherman can be expressed as (1)

$$Max \int_0^{\infty} e^{-rt}\, q_i\ (\mathrm{p} - \mathrm{w} - \mathrm{s})dt$$

where p is the price of the fish, w is the harvesting cost per unit of catch, s is the price of a unit of quota and q the number of quota units which is equal to the harvest. Arsason

(1990) shows that that the one period inverse net demand function for quota is s = p-w. Moreover, as noted by Epstein (1981) equation (1) gives the firm's plan at a t=0. The prices then denote market prices at t=0, which are expected to persists indefinitely. As the base period changes and new market prices are observed, the firm revises its expectations and its previous plan. Following Arnason (1990), one can show that the value of the quota at t=0, S_0 for the firm in question is

$$S_0 = Max \int_0^{\infty} e^{-rt} \, (pq - wq) \, dt$$

This is then the cash flow provided by the quota or the resource rent harvested by this firm. Hence, this is the maximal amount the firm will be willing to pay for the quota.

Taxes (on catch or on fishing effort) and allocated transferable vessel (catch or effort) quotas would in theory serve to correct the misallocation of resources resulting from the common-property externality. Moreover they are mathematically equivalent in their effect on effort use, and hence on economic efficiency. The explanation of this equivalence is simply that quotas, being limited in total quantity acquire a scarcity value, which by the assumption of transferability becomes reflected in the quota market. However, taxes have not been the regulatory instrument of choice in fisheries. The obvious reason is that taxation does not benefit fishers, and they have political clout in lobbying against taxation.