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Efficient management of ocean fisheries*

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This paper considers the problems of efficient management of common property ocean fisheries. The paper forwards the proposition that Pigovian taxes do not constitute a feasible method for fisheries management due to their huge data requirements. It appears, on the other hand, that the fundamental production externalities in ocean fisheries may in many cases be eliminated by instituting an appropriately designed system of property rights. A particular management method based on individual property rights in the fishery and discussed in the paper is not only capable of restoring economic efficiency in valuable ocean fisheries, it is also extremely informationally efficient in the sense that very little centralized collection of information is required for its operation. A further important advantage of this particular method is that it generalizes in a straightforward manner to multispecies fisheries. It appears, moreover, that this approach may also be applied to other cases of inefficient use of common natural resources.

1. Introduction

Ocean fisheries have traditionally been organized according to the principle of laissez-faire. For most of history anyone interested in exploiting ocean fish stocks has been free to do so. Only in this century, as a consequence of the decline and even collapse of many previously valuable fisheries, has the suitability of the institution of laissez-faire fisheries come under serious question. Recently, many coastal nations have asserted sovereignty over significant parts of the world's fishing grounds. Within exclusive national jurisdictions, however, the prevalent organization of the fisheries is still free access for domestic firms.

It is now well established that the traditional laissez-faire organization of ocean fisheries is economically wasteful. Each fishing firm, by extracting from limited fish stocks, reduces the harvesting possibilities of other fishing firms. The fishing firms impose, in other words, production externalities on each other. In ocean fisheries these externalities are so pervasive that, under the laissez-faire organization, the long term economic outcome, or Nash equilibrium, is a near or complete dissipation of economic rents irrespective of the potential productivity of the fisheries.

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While the Coase bargaining solution does not offer a promising remedy for externalities in fisheries, Pigovian taxes appear to provide a theoretically sound solution. The inefficiency of laissez-faire fisheries appears as excessive fishing effort. Under fairly general conditions, however, individual fishing effort is a continuous, decreasing function of tax on landed catch. Moreover, a high enough tax rate will completely choke off fishing effort. Clearly, given a relationship of this nature, any desired path of aggregate fishing effort may be generated by choosing the appropriate tax rates.

The drawback, however, is that to calculate the correct Pigovian tax, it is necessary to know practically everything about the fishery. Thus, the fisheries manager must have full knowledge of the details of the resource growth function as well as the harvesting and cost functions of all the firms participating in the fishery. Having obtained this information, the fisheries manager must solve the profit maximization problem for every firm to estimate its particular effort-tax response function. Finally, the fisheries manager must solve the overall profit maximization problem in the fishery to determine the appropriate tax rate. Clearly these requirements exceed the capabilities of any fisheries manager. Thus, while the Pigovian tax approach is theoretically capable of restoring efficiency in ocean fisheries, it is not empirically practicable.

3. Individual transferable share quotas

A fundamental reason for the failure of the laissez-faire system in ocean fisheries is the lack of private property rights. Under the laissez-faire framework fish stocks are a common property. Consequently, no-one is liable for the stock externalities imposed. If, on the other hand, well defined private property rights existed, a Coase type bargaining solution to the externality problem might be feasible.

This observation suggests that, if private property rights could be instituted in ocean fisheries, the usual efficiency properties of the free enterprise system might be restored. Unfortunately, as in the use of many other natural resources,[5] the usual instruments of private property rights, such as titles and location, are difficult to apply in ocean fisheries. After all most fish stocks are migratory and individual fish can usually not be identified as belonging to a certain owner.

It appears, however, that individual quantitative harvesting rights or catch quotas may constitute an adequate substitute for private property rights in fisheries. Provided such quotas are permanent, transferable and perfectly divisible they constitute true property rights in the sense of Scott (1989).

There are many conceivable versions of the individual catch quota system,

[5]Such as unpolluted breathing air.

some of which may be more amenable to effective fisheries management than others. One specific variant, called the individual transferable share quota system (ITSQ), exhibits particularly useful management properties.

In the ITSQ system each firm's permitted rate of catch is bounded above by its holding of a catch quota. Individual firms' catch quotas are calculated as a simple multiple of the total allowable catch in the fishery and the firms' share therein. These shares, which may be referred to as share quotas, constitute the basic property rights in the fishery. As more conventional assets, they are permanent, perfectly divisible and transferable. In fact, the share quotas are similar to many commonplace financial assets such as purchase options or shares in limited companies. The total allowable catch or total quota is determined by the fisheries manager.

Given these attributes of the share quotas, a market for trading these quotas will develop. In what follows we will adopt the extreme assumption that this market is perfect in the sense that transaction costs are negligible and a temporary equilibrium is continuously maintained. By trading in the share quota market individual firms can adjust their holdings of share quotas. In a profitable fishery the share quota price will be positive and profit maximizing fishing firms will not hold unused quotas.[6]

Since the share quotas are perfectly divisible and tradeable in a perfect market, standard arbitrage arguments immediately yield the result that the total quota will always be allocated to the most efficient fishing firms in the most efficient proportions. If that were not the case, there would exist opportunities for profitable trades in the quota market. Hence, it should be clear that the share quota system as defined above, will generate micro- (or allocative) efficiency in the fishery.

Following a standard modelling approach in aggregative fisheries economics,[7] firm i's instantaneous profit function may be taken to depend on its share quota, the total quota and the available stock of fish. More precisely, we may write this profit function at time t as:

$$F(q(i), x),$$

where i is an index referring to firm i. $q(i)$ represents the firm's quota equalling $a(i)\cdot Q$, where $a(i)$ is its share quota and Q the total quota. x represents the size of the fish stock.

The optimal quota holding condition for firm i is:[8]

$$r\cdot s = s' + F_q(q(i), x), \tag{1}$$

where r represents the rate of discount and s the market price of share

[6]For a proof of this assertion see Arnason (1990a).
[7]See Clark (1976) and Arnason (1990a).
[8]For detailed derivation of this and later equations see Arnason (1990a).

fisheries manager has to do to become privy to the same information is to monitor the share quota price.

4. Ecological fisheries management

All fish stocks belong to an ecological system. The stock dynamics of species belonging to a common ecological system are interdependent. This means that the biomass growth function of each species depends on the state of all the other species in the ecology. It follows that harvesting of one species will influence the opportunities for harvesting other species. Ecological interactions greatly complicate the population dynamics of fish stocks giving rise to the possibility of multiple equilibria and biomass bifurcations or catastrophes. Current biological knowledge about ocean ecologies is limited. Nevertheless, to attain full economic efficiency, management of fisheries must take the best possible account of these ecological relationships.

The share quota management technique described above can be generalized to the ecological context with only minor modifications. The fisheries manager should simply impose the system of individual transferable share quotas (ITSQ) for all relevant species and then set total catch quotas so that the aggregate value of all quota prices is maximized. Thus, instead of announcing a total quota for a single species the fisheries manager must announce a vector of total quotas for all relevant species in the ecology. As before, profit maximizing fishing firms may be relied on to gather and interpret the pertinent biological and economic information in the most efficient manner. Given this, there will be a vector of total quotas that maximizes aggregate resource rents from utilizing the ecology. On the assumptions discussed above, this vector constitutes the best fisheries policy.

An interesting feature of ecological fisheries management with the help of share quotas is that some share quota prices may well be negative. The reason is that the optimal ecological fisheries policy will usually require the reduction in the stock size of some species of fish that are themselves not valuable but prey on or compete with commercially valuables species. The quota price for these species would be negative representing harvesting subsidies. In this case, contrary to the one of positive quota prices, profit maximizing quota holders would prefer not to spend economic resources catching their share quota. Therefore, in the case of negative quota prices, the additional requirement that quotas be fulfilled must be imposed.[10] It may be noted that a negative quota price with the requirement of fulfilment corresponds to a payment for the eradication of pests and predators that is commonplace in traditional agriculture.

[10]Moreover, for a similar reason it may become necessary to keep track of who actually holds negatively priced share quotas.

Table 1

Total quota and share quota price: Possibilities.

	Total quota, Q	
Quota price, s	Negative	Positive
Negative	Profitable stock enhancement (ocean ranching)	Unprofitable fishery predator/competitor stock reduction
Positive	Unprofitable stock enhancement	Profitable fishery (commercial fishery)

Another interesting feature of ecological fisheries management with the help of share quotas is that optimal total quotas for some species might be negative. This means that the corresponding share quota holders would be under the obligation of enhancing the species in question to the extent stipulated by their quota holdings.[11] Thus, it appears the ecological fisheries management with the help of share quotas naturally accommodates fish stock enhancement as a dual to harvesting. If the quota price for a negative quota share is positive it represents a subsidy for fish stock enhancement. That would occur in the case of socially optimal but privately nonprofitable stock enhancement. Alternatively, stock enhancement may be privately profitable. A case in point is ocean ranging valuable species. For ecological reasons the quota price would normally be negative indicating that the ocean ranching firms would pay for the privilege of releasing fish into the ocean.[12] For convenience, the polar cases of ecological fisheries management are summarized in table 1.

As previously mentioned, the fisheries management rule in the ecological context is essentially the same as in the case of a single species. The quota manager should attempt to maximize the sum of share quota prices. Notice, however, that in this general case that where quota shares may be negative, the quota prices must be multiplied by negative unity when the total quota is negative. Thus, more formally, the management rule is:

$$\max_{\text{all } Q(j)} H(\boldsymbol{Q}) = \Sigma_j s(j) \cdot \Omega(j), \tag{3}$$

where $\boldsymbol{Q}$ represents the appropriate vector of total quotas and $\Omega(j) = -1$ if $Q(j) < 0$ and $\Omega(j) = 1$ when $Q(j) > 0$.

In the ecological context, the task of locating the maximum of the $H(\boldsymbol{Q})$

[11]Actually it is a matter of indifference whether such quotas are regarded as negative catch quotas or positive enhancement quotas.

[12]At the same time the optimal total quota of competing species would normally increase see Arnason (1990b).