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EXTERNAL EFFECTS AND MARINE FISHERIES;

A REVIEW OF SOME CONCEPTS AND PROBLEMS

by

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INTRODUCTION

The aim of this paper is to explain the concept of "external effects", or "externalities", and see how it relates to the problem of achieving optimal use of a "common property resource", the marine fisheries. "Externalities" and "common property resources" are closely linked. The amount of literature on the topics is vast, but to some extent unclear and confusing. I hope to give the reader an understanding of some main concepts and problems as I have perceived them.

The term "common property resources" is frequently used, although infrequently defined. The term may be used for "situations of common ownership and usage of a resource by decision makers who are otherwise independent". (STEVENS, 1967, p. 153). The areas of commonality of most current concern, using Stevens' broad definition, are:

1. Environmental quality issues, including water and air quality, recreation quality, and esthetic values.

2. Production from the use of marine resources, including ocean fisheries.

3. The allocation of ground water among uses and time periods.

4. Production from the use of publicly owned forest, range, and mineral resources.

It is the lack of clear identification of <u>property rights</u> and the <u>public good aspect</u> of the resources that is at the heart of the problem. It is not so much that the resources are actually owned in common. Therefore, a term such as "common pool resources" may be more appropriate.

As mentioned, the literature on "externalities" and "common property resources" is to some extent unclear and confusing. For example, HAVEMAN (1973) distinguishes between common property, the public good nature of certain resource flows, and external diseconomies as three separate types of market failures. On the other hand HERFINDAHL and KNEESE (1974) state that " ... with respect to externalities, the central problem is 'common property'" (p. 51). But they do not include what BATOR (1958) calls "public good externalities" in their concept of external effects. Haveman includes resources such as oil pools, fisheries, and publicly owned forests and grazing lands, in his "commons". He associates externalities with water and air pollution separately from the concept of "common property". But Herfindahl and Kneese say that water and air pollution occur to unwarranted degrees because air and water are assets held in common. And BAUMOL and OATES (1975) blame water and air pollution on the type of externalities they call "undepletable", which are associated with the public good aspect. It is confusing.

The uncertainty and inefficiency generated by non-existing or ambigous property rights and the existence of public good characteristics have received considerable attention in the literature. But there is a myriad of relatively unique complexities surrounding the various resources. This may be some of the reason for the great variability of approaches to the "common property problem" and the lack of conceptual unity. The process of arriving at a useful concept of analysis is slow and painful. Someone begins with one example or observation, followed by a theory which is intuitively plausible. A theoretical term associated with a vague concept is coined. Examples of a seemingly different kind emerge which call for another theory. The process goes on. As examples and theories continue to accumulate, the different

categories under the same heading serve only to confuse, and each associated theory becomes ad hoc. When reading some of the large quantity of literature on externalities and common property resources, one may get a little bit of that feeling. Nevertheless I hope to be able to explain some main elements in the existing theory on externalities and marine fisheries.

If we use a broad definition of "common property resources" as indicated by Stevens, marine fish resources is only a small part of a large class of resources including the air and most water. Using the concept of external effects as explained in the first section of my paper, such effects are likely to produce inefficient situations when there exist direct interdependencies between users of common property resources that are not under unified management. But the kinds of externalities occuring, may be different for different resources, depending on the qualities of each resource. Some resources, like air, have "public good" characteristics and are "undepletable". Hence "public good" or "undepletable" externalities occur. Other resources, like the marine fish resources, are "depletable", and "depletable" externalities occur. And there may be mixed cases.

In the first section of my paper I will be concerned with the concept of externalities in general. Then, in the second section, I will show how the existence of externalities leads to dissipation of rent from and inefficient use of marine fishery resources. Here I will also touch upon some other aspects of the theory of marine fisheries.

EXTERNAL EFFECTS

External effects first appear in MARSHALL's Principles (1925) as external economies in connection with a competitive industry's downward sloping supply curve. But little attention was given to this concept until it was developed and extended in PIGOU's Economics of Welfare (1946). External effects or "externalities" as they are referred to, today provide the standard exception to the equation of optimality with universal perfect competition. It is the chief cause of divergency between "private net product" and "social net product".

There has been, and still is, a substantial degree of confusion in the theory and terminology regarding external effects. The externality is in some ways a straightforward concept; yet, in others, it is extraordinarily elusive. We know how to take account of it in our analysis, and we are aware of many of its implications, but, despite a number of illuminating attempts to define the notion, one is left with the feeling that we still have not captured all its ramifications.

Classification of types of externalities is also difficult. But it is important since there are classes of externalities whose formal properties and policy implications differ significantly.(BAUMOL and OATES, 1975, p. 15). First we distinguish between technological and pecuniary externalities. Then we may distinguish between two categories of technological externalities, namely what BATOR (1958, pp. 465-471) calls "ownership" and "public goods" externalities. Favorable external effects are often called external economies, while adverse external effects are called external diseconomies.

The "real" external effects, which cause divergence between private and social cost-benefit calculations and thereby misallocation of resources, are the technological externalities. Pecuniary externalities is a category of pseudo-externalities which need not produce misallocations of resources. Pecuniary external effects work through the price system, while the real external effects are experienced through "direct interaction". Such interaction, whether it involves producer-producer, consumer-consumer, producer-consumer, or employer-employee relations, consists in interdependencies that are external to the price system, hence not accounted for by market evaluation. It implies the interdependence of various utility and production functions. A broad definition of an external effect is suggested by MISHAN (1965) as a "situation in which relevant effects on production or welfare go wholly or partially unpriced". He also distinguishes between external effects <u>internal</u> to the firm or industry and external effects <u>external</u> to the firm or industry.

We find a good attempt to define and clarify the concept of external effects in BAUMOL and OATES (1975). They use two conditions in the definition:

> Condition 1: An externality is present whenever some individual's, say A's, utility or production relationships include real (that is, non-monetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare. (p. 17).

This definition should not be misunderstood to be a simple equation of externalities with economic interdependence. When I rely on the farmer for my food, no externality is involved, for he does not decide for me how many potatoes I will consume, nor does my consumption enter directly into his

utility function. The definition also rules out cases in which someone deliberately does something to affect A's welfare, a requirement that MISHAN (1969, 1974) has emphasized.

> Condition 2: The decision maker, whose activity affects others' utility levels or enters their production functions, does not receive (pay) in compensation for this activity an amount equal in value to the resulting (marginal) benefits or costs to others. (p. 18).

This second condition is required if the externality is to have all the unpleasant consequences, including inefficiencies and resource misallocation, that are associated with the concept. It has been long recognized that, at least in some cases, proper pricing or tax-subsidy arrangements will eliminate the misallocations. Nevertheless, one may prefer to define an externality to be present whenever condition 1 holds, whether or not such payments occur. If optimal taxes are levied, smoke generation by factories will no doubt be reduced, but may not be reduced to zero. In that case, it seems more natural to say that the externality has been reduced to an optimal level, rather than asserting that it has been elimiated altogether. So Baumol and Oates conclude that they will say that an externality is present if the activity satisfies condition 1.

Familiar examples today of external effects, include the adverse effects on flora, fauna, rainfall, and soil, in cutting down the trees of a forest; or the effects on the mosquito population of creating artificial lakes, and other ecological repercussions that ultimately touch upon the welfare of people. Other external effects are the congestion suffered by all the traffic from additional vehicles coming onto the roads; or the noise and pollution arising from the operation of industry or of its products; or the loss of life consequent upon the increase in air or ground traffic. The

number of external effects in the real world are virtually unlimited. A cigarette smoked in the presence of non-smokers has adverse external effects. Attractive short-skirted women may generate adverse external effects on other women and favorable external effects on men. And so one could go on.

It emerges that one characteristic common to all these external effects is the incidental, or unintentional nature of the effect produced.(MISHAN, 1974, p. 86). The person or industrial concern engaged, say, in logging may, or may not, have any idea of the consequences on the profits or welfare of others. But it is certain that they do not enter into his calculations. The factory owners, whose plant produces smoke as well as other things, are concerned only to produce things that can be sold on the market. They have no interest in producing smoke, even though they may be fully aware of it. But so long as their own productivity does not suffer thereby, and they themselves are not penalized in any way, they will regard the smoke as an unfortunate by-product.

If these external effects are not deliberately produced, neither are they deliberately absorbed by others. Such effects may add to the enjoyment of life, as does the smell of fresh-cut grass, or else add to life's vexations as does the noise, stench, and danger of mounting automobile traffic. But they are not within the control of the persons who are absorbing them -- at least not without their incurring expenses.

To make the explanation of external effects a little more analytically clear, I will build on E. J. Mishan's article "The Postwar Literature on Externalities: An Interpretative Essay".(MISHAN, 1971). Mishan's definition of external effects is very similar in spirit to Baumol and Oates'. To repeat; an external effect occurs when the activities of one economic

entity -- producer, consumer, unit of government -- have a direct impact on the production or preference functions of a fiscally independent entity. By "direct" is meant that the effect occurs without any intermediary economic transaction. The discharge of waste water by an upstream entity which has adverse effects on downstream producers or consumers serves as a good illustration.

Mathematically, the presence of an external effect can be shown by the following notation:

$$U^1 = F^1 (x_1^1, x_2^1, \ldots, x_m^1; x_n^2)$$

Here, an external effect by some entity 2 on some entity 1 is depicted. If F^1 is taken to stand for the preference function of a consumer, the x's are the amounts of goods $\underline{\bar{X}}_1, \underline{\bar{X}}_2, \ldots, \underline{\bar{X}}_n$ used by him and x_n^2 the amount of some good $\underline{\bar{X}}_n$ used by person 2, or produced by an industry 2. Again, F^1 can stand for the output of a firm or an industry, in which case the x^1's are the amounts of it's inputs, while x_n^2 is the amount of input or output from some other firm or industry. Alternatively, F^1 can stand for the total cost of all the goods $\underline{\bar{X}}_1$ to $\underline{\bar{X}}_n$ produced by firm 1, where costs depends not only on the amounts produced of these goods, but also on x_n^2, the amount of good $\underline{\bar{X}}_n$ produced by firm 2. However, the notation does not succeed in conveying that the external effect produced is not a deliberate creation, but an unintended or incidental by-product of some otherwise legitimate activity. The external effect may be either favorable or unfavorable.

An externality experienced by entity 1 as a result of the marginal unit of entity 2's equilibrium level activity is indicated by the term:

$$\frac{\partial F^1}{\partial x_n^2} \neq o$$

Assume that entity 2 is a productive enterprise, and let p_n^2 and c_n^2 stand for price and marginal cost of any output of the good $\bar{X}_n$ chosen by entity 2. If the existing externality is ignored by entity 2, and if it is a competitive enterprise, it will, as internal efficiency requires, choose to equate c_n^2 to p_n^2. But then, $(p_n^2 - c_n^2) + \frac{\partial F^1}{\partial x_n^2} \neq 0$. The externality then has allocative significance at the margin of the existing equilibrium, and corrective action is called for. If it is an external cost that is being imposed, the inequality means that the marginal cost to the broader society exceeds the marginal cost to the producer. Because he equates his internal marginal cost to price, the social marginal cost exceeds the price consumers are willing to pay for it.

It is generally recognized that the resource misallocation attributable to an externality will occur only when an appropriate price is not charged by (to) the supplier of some such services (or disservices). But why will such services exist in the economy? Why should there be some activities whose producers escape the workings of the price system?

BATOR (1958, p. 470) points out that many externalities partake of the character of public goods. The defining quality of a pure public good is that "each individual's consumption of such a good leads to no subtractions from any other individual's consumption of that good" (SAMUELSON, 1954, p. 387), hence "it differs from a private consumption good in that each man's consumption of it, $\bar{X}_2^1$ and $\bar{X}_2^2$ respectively, is related to the total $\bar{X}_2$ by a condition of equality rather than of summation. Thus, by definition, $\bar{X}_2^1 = \bar{X}_2$ and $\bar{X}_2^2 = \bar{X}_2$".(SAMUELSON, 1955, p. 350). If the air in a city is polluted, it deteriorates simultaneously for every resident in the area and not just for any one individual. My breathing of polluted city

air can (to a reasonable degree of approximation) be taken to leave unaffected the quality and quantity of the air available to others. Air pollution, then, is clearly a public "bad". It is difficult to think of many examples of pure public goods. In most cases, some type of "congestion" will arise with increased use, introducing the "if more for you, then less for me quality". "But as long as activities have even a trace of publicness, price calculations are inefficient". (BATOR, 1958, p. 475). The ordinary price system just will not do where a public good is involved. In the case of a pure public good, Pareto optimality requires a zero price since marginal cost is zero. Obviously no private exchange system would result in the production of such a pure public good.

Many externalities are due to the "public" qualities of great many activities. For example, the externality associated with the generation of ideas, knowledge, etc., is due in good part to the public character of these "commodities". Many interconsumer externalities are of this sort. The same consumption item may enter, positively or negatively, several persons utility functions while the amount consumed by one person does not affect how much the others will consume. If I make a nice garden, incidental by-passers may enjoy the view of it without influencing how much I may enjoy the view. If I erect a television aerial, my close neighbor may be able to connect his television without inflicting any loss on me.

Rather than referring to these as public good externalities as Bator does, Baumol and Oates call them <u>undepletable</u> externalities (BAUMOL and OATES, 1975, p. 19), to emphasize the fact that an increase in the consumption of the good by one individual does not reduce the availability to others. This characteristic is referred to as "jointness in supply" by HEAD (1962).

He also clarifies the fact that jointness in supply (undepletability) and the possibility of exclusion are separate matters. An externality may be undepletable and yet satisfy the excludability requirement that is often taken to be violated by public goods. I can exclude travellers from crossing my bridge by charging a price for it. However, as long as there is no congestion, no other person would suffer a loss if the crossing was made. This causes a clear-cut violation of Pareto optimality which requires that every action be taken that can make one person better off without making someone else worse off.

However, the major source of depletable externalities lies in institutional impediments that effectively prevent the assignment of property rights permitting the implementation of normal market exclusion and pricing procedures. In fact, what Baumol and Oates call depletable externalities are called ownership externalities by Bator. An example of a depletable externality is given by Baumol and Oates:

> In the postwar period, when there was a severe shortage of fuel, it is reported that in several parts of Europe many persons spent a good part of their time walking along railroad tracks looking for coal that had been dropped by passing trains. It is clear that this is a depletable externality because every bit of coal found by gatherer A meant that so much less was available to B. (BAUMOL and OATES, 1975, p. 20).

The reason coal was left along the tracks is that the railroad did not find it worth the cost of gathering the coal and selling it at a price. The point is quite general: Where there are no legal or institutional restrictions inhibiting the pricing process, a depletable externality will usually be permitted to exist only if the cost of collecting a price for it exceeds the potential gains. Either the externality must be insignificant or the cost of collecting an appropriate fee must be very high. But, as

already stated, the major source of depletable externalities lie in institutional difficulties of assigning property rights permitting normal market exclusion and pricing procedures.

An external effect caused by institutional difficulties causing scarcity to be divorced from effective ownership, may be demonstrated by means of a simplified variant of a production model suggested by MEADE (1952) and used by BATOR (1958, pp. 462-463): Assume a world of perfect competition where a single purchasable or inelastically supplied input, labor (L), is used to produce two homogeneous and divisible goods, apples (A) and honey (H), at nonincreasing returns to scale. But while the output of A is dependent only on L_A: $A = A(L_A)$, honey production is sensitive also to the level of apple output: $H = H(L_H, A(L_A))$. Both functions are assumed homogeneous of degree one, and apple blossoms are exhaustible, rationable "private" goods: more nectar to one bee means less to another.

By solving the usual constrained maximum problem for the production-possibility curve, it can be shown that Paretian production efficiency implies

$$p_H \frac{\partial H}{\partial L_H} = w \qquad \text{(I)}$$

$$p_A \frac{\partial A}{\partial L_A} + p_H \frac{\partial H}{\partial A} \frac{dA}{dL_A} = w \qquad \text{(II)}$$

where p_H, p_A, and w represents the prices of honey, apples and labor, respectively. Equation (I) is consistent with profit maximizing by the honey producer. Each honey producer will do what he must for efficiency: hire labor until the value of its social as well as private marginal product equals the wage rate. But not so for the apple producers. Their profit maximizing production decision will be based on $p_A \frac{dA}{dL_A}$ and hence be

inefficient unless $\frac{\partial H}{\partial A} = o$, i.e. unless the effect of apples on honey is zero. Specifically, if apples have a positive external effect on honey output, market determined L_A will be less than desired. A Pareto-efficient solution will associate with apple blossoms a positive Lagrangean shadow-price. If, then, apple producers are unable to protect their equity in apple-nectar and markets do not impute their correct shadow-value, profit-maximizing decisions will fail to correctly allocate resources (e.g. L) at the margin.

The divorce of scarcity from effective ownership is hence the binding consideration. Certain goods or bads with determinate non-zero shadow-values are not attributed in such cases. It is irrelevant here whether this is because the lake where people fish happens to be in the public domain, or because "keeping book" on who produces, and who gets what, may be impossible, clumsy, or costly in terms of resources. More generally, it could as well be due to difficulty in knowing who "produced" the "benefit" -- oil wells drawing on the same pool is an example. The owner cannot protect his own, in fact it is difficult to know what one means by "his own".

The important point is that the difficulties reside in institutional arrangements, the feasability of keeping tab, etc. Apple nectar has a positive shadow price, which would, if only payment were enforceable, cause nectar production in the precisely right amount and even distribution would be correctly rationed. The difficulty is due exclusively to the difficulty of assigning and policing property rights and keeping accounts. Many of the examples of interproducer external effects are of this type; in "shared deposits" of fish, oil, water, etc. Though in some of these cases, indivisibility elements also enter. This means that even if property rights were possible to enforce, inefficient production may result due to monopoly power.

The ability to exclude is an essential concept regarding ownership (depletable) externalities. Jointness in supply (public goods) can exist quite independently of exclusion possibilities. But with respect to ownership externalities, the central problem is "common property". Market exchanges cannot place a price on the resources to reflect their scarcity value. In production of oil there is a "common pool" problem which means that the individual producer has no incentive to consider the costs his pumping imposes on other producers -- reduced gas pressure, for example. An equivalent situation is true for marine fisheries. Each fisherman has no incentive to consider the fact that his entry will impose costs on all fishermen due to reduced stock of fish and congestion on the fishing ground. Each fisherman will only perceive and make decisions on the basis of average products and average costs -- not on the basis of marginal products and marginal costs, which would be required to achieve Pareto optimality. The result is excessive fishing activity.

An appropriate price can prevent any misallocation induced by the presence of depletable externalities. (BAUMOL and OATES, 1975, p. 23). The price charged should simply be equal to marginal social cost (benefit). This is one case where taxes upon the generator of the externalities together with compensation of the victims at the same rate per unit will produce the desired results.

However, it is important to note that a depletable externality need not cause inefficiencies. As illustrated by the case of the coal collectors, it may be that the transaction costs (costs of exclusion or collection) are sufficiently high to make pricing of the externality unprofitable both socially and privately. In such cases, the continuation of an "uncorrected"

externality obviously may be consistent with Pareto optimality. The potential gain may be smaller than minimal costs and efforts needed for the necessary arrangements. These are then uneconomic in the sense that once the costs and efforts enter the calculus, the net potential benefits are negative. "To adjust for externalities, we always need to consider specifically the required institutional mechanisms, the feasability of such schemes, the attendant equity considerations, or the relative social costs of implementing such schemes." (STEVENS, 1967, p. 169). Most often, the consideration of these costs and Pareto efficiency will result in a partial elimination of adverse external effects, but not in their complete elimination.

In the case of depletable externalities an extension of the ordinary price system can serve as an effective allocation mechanism. This is known as internalizing the external effects into the price system. In contrast, where the externalities are undepletable, no price can do the job. It has long been recognized that no ordinary price system will produce a satisfactory allocation of resources to public goods. The trouble in this case is that optimality requires a pricing asymmetry: a non-zero price to the supplier of the externality (a positive price for an external benefit and a negative price for an adverse externality) and a zero price for the consumption of the externality. Obviously, no price can simultaneously be zero and non-zero; the price system is thus inherently incapable of dealing with such cases. (BAUMOL and OATES, 1975, p. 24). An example: Suppose a number of competitive firms raise flowers for sale to commercial florists and by their industry's custom admit visitors to their uncrowded gardens without admission charge. Obviously the number of gardens supplied in

these circumstances is likely not to be optimal. The potential marginal private yield of a garden will typically be less than its marginal social yield, for the private returns do not include the value it brings to the visitors who will see it each day. Firms will provide an optimal number of gardens only if they charge an admission price to visitors in addition to the price they can obtain from the sale of their crop. The difficulty is that any nonzero price must also produce an inefficiency. The fee will generally discourage some visitors from coming to the garden, and, because, the marginal social cost of an additional visitor is zero, this is clearly undesirable.

Baumol and Oates go on to say that no ordinary price can meet this requirement, while, however, a tax or subsidy can. One of the remarkable properties of this device is that it can assume either the symmetry required in the depletable case or the asymmetry called for when externalities are undepletable. The tax or subsidy to the supplier serves as the required nonzero price for the externalities he generates. Symmetry can then be achieved in the depletable case by using the proceeds (positive or negative) to compensate those who are affected by the externality. Similarly, the asymmetry in the undepletable case can be attained by simple absorption of the tax proceeds into the public treasury, so that charges to consumers of the external effect are then zero, as optimality requires.

In the case of a tax, the producer of the externality is permitted to deal with this tax in whatever way seems best to it. If it is cheaper to eliminate the effect or to reduce it, thereby avoiding a part of the tax, the firm will be stimulated to do this. If such means are not available, the tax will influence the firm in deciding on how much it is going to produce in light of the costs that are imposed on other individuals.

For an activity generating an external diseconomy, the required excise tax is equal to the value of the marginal external diseconomy at the optimal output. For any good generating an external economy, an excise subsidy equal to the value of the marginal external economy at the optimal output should be offered to the producers. Clearly, the effect of these measures is, in the former case, to reduce output below its competitive equilibrium and, in the latter case, to expand output beyond its competitive equilibrium. (MISHAN, 1971, p. 7).

Still another way of handling an external effect, assuming that one has information about the value of the effect and about the cost of alternative ways of dealing with it, is to impose certain standards. One possibility is to ban the output of the external effect completely. (HERFINDAHL and KNEESE, 1974, p. 52). But external effects should not necessarily be eliminated to achieve efficiency. As mentioned before, the elimination of externally imposed costs or their reduction will, in turn, entail additional costs, and we may be better off as a group by continuing to suffer some of the external effect rather than by reducing or eliminating it. In the case of external economies, it might be desirable to organize in such a way as to increase them.

I would like to return to the role of property rights and the possibilities of internalizing depletable external effects. The function of allocating resources to alternative ends has traditionally been accomplished in our society by private exchange. Modern welfare economics concludes that if: (1) preference orderings of consumers and producers are independent and their shapes properly constrained; (2) consumers maximize utility subject to given income and price parameters, and (3) producers maximize profits

subject to the price parameters; a set of prices exists such that no individual can be made better off without making some other individual worse off. (HERFINDAHL and KNEESE, 1974, p. 359). For a given distribution of income, this is an efficient state. Given certain further assumptions about the markets, this Pareto optimum can be achieved via a pricing mechanism and voluntary decentralized exchange.

However this exchange process breaks down unless all (or reasonably all) desirable services yielded by material objects or people can be reduced to private ownership without monopolization. In the social economics of private production from natural resources, instances of such breakdown has been observed, analyzed, and policies devised to deal with them, at least to some degree. This is true, for example, for the common property problems in the petroleum and fishing industries. I will return to the case of the fishing industry in the next section. In both of these cases the situation may be viewed as a "market failure" in a partial equilibrium sense.

In recent literature on externalities, the concept and its significance have been considerably clarified by analyzing it in terms of the possibilities of bargaining and monetary exchanges between the parties involved in the externality. This discussion has evolved around the concept of property rights and what has come to be known as "transaction costs". Several authors have pointed out that external effects can in some instances be brought under optimal control by defining property rights to what was previously common property or by merging activities having external effects on each other (the "sole owner" case in fisheries). This is what is known as internalizing the external effects. The effect then gets property priced, either externally in a marked exchange, or it is given an internal price as

in the case of merging. The former case may be viewed as transforming the external effect, or incidental by-product, into a joint product. (MISHAN, 1974, p. 91). For example, straw might simply be one of the joint by-products of the threshing of wheat which happens to have value for some of the poorer peasants who habitually gather it for fodder or for filling mattresses. It would, however, cease to be an external effect if the farmer excercised his property rights of the straw and the demand for it grew so that a market for straw came into being. Both grain and straw would then become intentionally produced and jointly marketed, and the demand prices of both together would be equated to the marginal resource cost of wheat production. An example of the latter case (merging) would be the case of two firms along a river, and these firms being the only economic entities involved so that no public good characteristics are involved. The upstream firm discharges waste water to the stream and imposes an external cost on the other firm downstream. Then the two are merged and the external effect is made internal to the enterprise. The upstream unit would now find it worthwhile to take into account any effects on the downstream unit in making its production decision. The practical value of this conclusion is, however, limited. The typical pollution situations involve numerous affected entities.

It might also be possible to define a property right to the "commons" such that exchange between independent entities could take place. For example, again in the case of the upstream and downstream firms, if the upstream firm was accorded a clear right to discharge its waste waters, then the downstream firm could purchase part of this right to protect itself against damage. It would pay the damaged party to continue to purchase units of the right until his marginal gain is equal to the marginal cost of the waste discharger for reducing the discharge.

The market internalization of the externality implies that, once priced, it comes under the control of that person, firm, or industry, which hitherto could only be a passive recipient. That is to say, beginning from a situation in which the function describing the response of a person, firm, or industry 1 is written as $F^1 (x_1^1, x_2^1, \ldots, x_m^1, x_n^2)$ the internalizing of x_n^2 now brings the value of the function under the direct control of 1, so that this original function is now to be written as $F^1 (x_1^1, x_2^1, \ldots, x_m^1, x_n^1)$. For the price of $\underline{\overline{X}}_n$ is now determined by the market along with the prices of all other goods and factors. To the extent that the levels of outputs and utility are dependent on $\underline{\overline{X}}_n$, they are, for everyone now affected only "indirectly" by price changes of $\underline{\overline{X}}_n$. (MISHAN, 1971, p. 4).

MARINE FISHERIES; A CASE OF COMMON PROPERTY RESOURCES

Three fundamental factors have explained the frequency with which "common property" is encountered in ocean fisheries: (1) For long periods scarcity in natural fish stocks was not a major constraint. (2) Even where stocks have become scarce, the overhead costs of enforcing fishery sovereignty or property rights have been or would have been exorbitant -- particularly because of the ecological intricacies involved. (3) Collective enforcement of sovereignty or rights has been hampered by an inability to decide on the basis on which national or individual benefits are to be distributed. (SCOTT and SOUTHEY, 1969, p. 47).

The first situation is now in general past, but the two others remain; and marine fish resources are largely what we may call renewable, but exhaustible, common property natural resources. In the early fifties GORDON (1954) demonstrated how common property leads to excessive fishing effort. SCOTT (1955) then introduced the "sole owner" in order to provide a contrast between the common property situation and individual property rights. The "sole owner" did not, however, have monopoly powers. TURVEY (1964) subsequently stressed the form as well as the quantity of effort. Then SMITH (1968, 1969) formally added the dimension of crowding. Furthermore he introduced taxing, assuming that neutral transfers can be made. Here I will to a large extent use the articles of Gordon, Scott, and Smith to explain the main characteristics of marine fisheries.

As stated by SCOTT and SOUTHEY (1969, p. 49), "externalities are the essence of fishery economics". The type of externalities we find, is of

the kind called "depletable externalities" by BAUMOL and OATES (1975). Their source is institutional obstacles to assignment of property rights.

KNIGHT (1924, p. 591) says that:

> ... any opportunity ... is a productive factor if there is sufficient demand for its use to carry into the stage of diminishing returns the application to it of transferable investment. The charge made by a private owner for the use of such an opportunity serves the socially useful purpose of limiting the application of investment to the point where marginal product instead of product per unit is equal to the product of investment in free (rentless) opportunities; and under competitive conditions this charge will be fixed at the level which does make marginal products equal, and thus maximizes productivity on the whole.

But the problem in the marine fisheries is that there is no private owner of the fishing opportunity to make the right charge. The opportunity is "owned in common", all fishermen have free access, and the resources are exploited under conditions of individualistic competition. The haul of one fisherman reduces the expected size of the catch of the others, but this does not affect his decision. Thus we have a clear case of a depletable externality. The result of individual maximizing behavior in this setting is an excessive level of fishing activity. Ever since KNIGHT's (1924) exposition of PIGOU's (1920) example of good and bad roads, which in a "titled mirror image" is seen in Gordon's analysis of the common fishing ground; models of fishery harvesting have followed the conclusion that, in equilibrium, the average product of fishing effort (or labor) equals the marginal factor cost (or the wage rate). Hence economic waste results, since the marginal product of labor in fishing is lower than that employed elsewhere. The equalization of the average product of labor to the wage rate leads to the dissipation of rent for the fishing ground.

Let us go back and look at the case of good and bad roads. Suppose that between two points there are two highways, one of which is broad enough to accommodate without crowding all the traffic which may care to use it, but is poorly graded and surfaced, while the other is a much better road but narrow and quite limited in capacity. As more trucks use the narrower and better highway, congestion develops, until at a certain point it becomes equally profitable to use the broader but poorer highway. The narrow road has the characteristics of an "increasing cost industry" while the broad road is a "constant cost industry".

The case may be shown by use of simple diagrams:

Figure 1

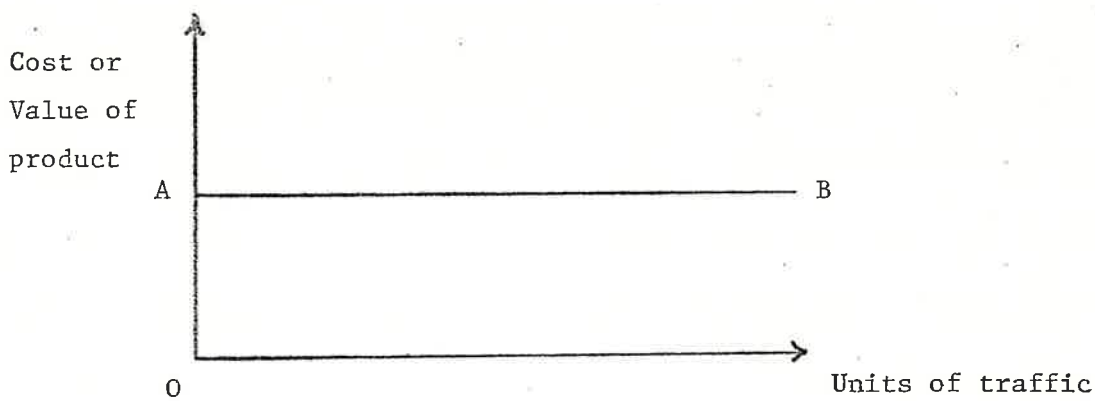


Figure 2

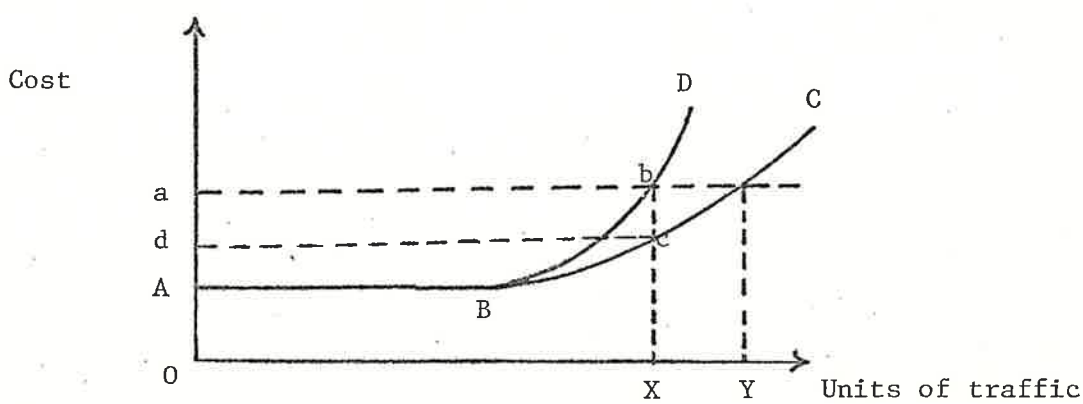
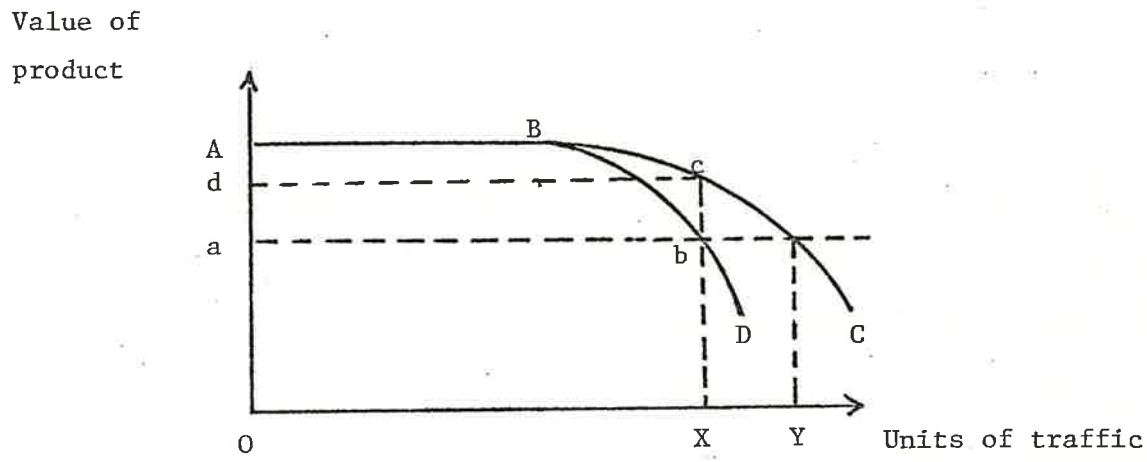


Figure 3



OA in Figure 1 = Oa in Figure 2 and Figure 3.

Figure 1 represents the case of constant cost or constant returns, the cost of successive units of output or the return from successive units of investment on the broad road. In Figure 2, the curve ABC is a cost curve for the narrow road, showing the costs of successive units of output. It starts at a lower level than the cost on the broad road, but at a certain point B, congestion sets in and increasing cost appears. Curve ABD is a curve of the marginal costs on the narrow road. When costs begin to increase, the marginal cost will increase more rapidly than the cost of the added unit, since the production of each additional unit raises the cost of the earlier units to the level with that of the new unit. Figure 3 represents the same facts as Figure 2, but in terms of product of successive units of investment, instead of the cost of successive units of output, that is, as curves of "diminishing returns" instead of "increasing costs". The curve ABC shows the actual product of the added unit of investment, and the curve ABD its marginal product, its addition to the total. The argument is the same, but stated in the reverse or reciprocal form.

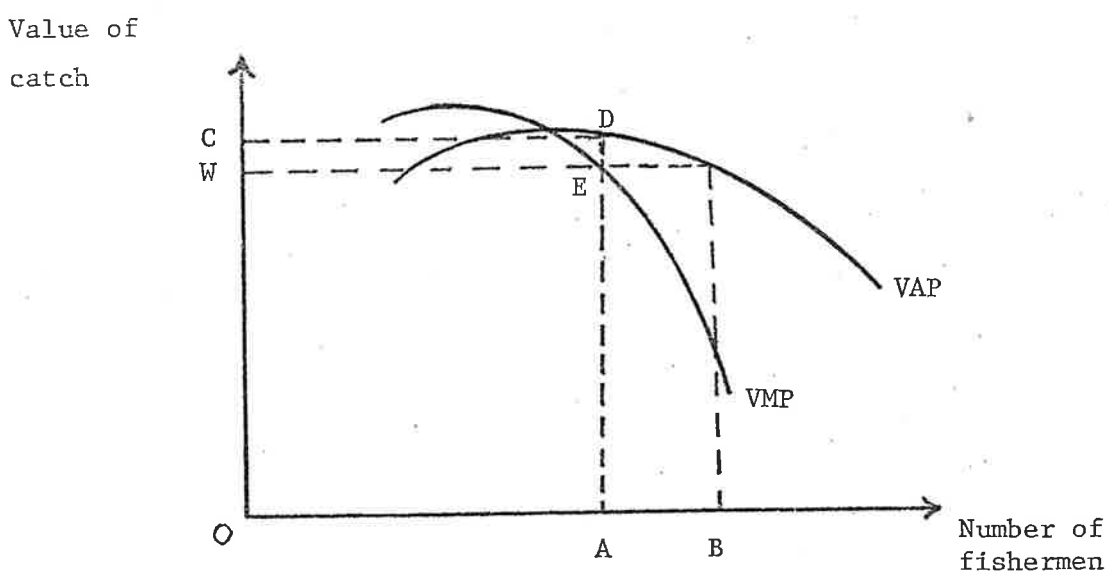
The adjustment of traffic between the two roads is correct when the marginal product of the last unit of investment on the superior road is equal to the product of a similar unit on the broad road. That is, traffic (investment) units should be added on the narrow road to the point X, and the rest should go to the broad road. But whenever there is a difference in the cost (or product), to an additional truck, of using the two roads, the driver of any truck has an incentive to use the narrow road, until the advantage is reduced to zero for all the trucks, at point Y. In such a case social interference seems to be clearly justified. If the government should levy a tax on each truck using the narrow road, the tax would be considered by the trucker as an element in his cost. It would cause the number of trucks on the narrow road to be reduced to the point where ordinary cost, plus the tax, became equal to the cost on the broad road, assumed to be tax free. The tax could be so adjusted that the number of trucks on the narrow road would be such as to secure maximum efficiency in the use of the two roads taken together. The revenue obtained would be a clear gain to the society, since no individual truck would incur higher costs than if no tax had been levied. The tax would be equal to "bc" and the revenue obtained equal to abcd in Figure 2 and 3.

The ideal situation would also be brought about through the operation of ordinary economic motives if the roads were subject to private appropriation and exploitation. The owner can charge a toll for the use of the narrow road, representing its "superiority" over the free road, in accordance with the theory of rent. The condition of equilibrium is that the rent on the superior opportunity is maximized as an aggregate. The toll or rent will be so adjusted that added product of the last truck which

uses the narrow road is just equal to what it could produce on the broad road. The toll would be equal to the previous mentioned tax, equal to "bc". No truck will pay a higher fee, and it is not to the interest of the owner to accept a lower fee. The traffic will take the narrow road out to the point X. This adjustment is exactly that which maximizes the total product of both roads, and maximizes the (aggregate) rent to the narrow road. The rent will be equal to the revenue in the tax case, abcd. The optimal situation has been reached. KNIGHT (1924, p. 586) states that "it is in fact the social function of ownership to prevent excessive investment in superior situations."

But in the case of the marine fisheries there are, as mentioned, problems in assigning and policing property rights. The result of unregulated individual maximizing behavior is then an excessive level of fishing activity. This may be illustrated with an argument basically similar to that of the road case.

Figure 4



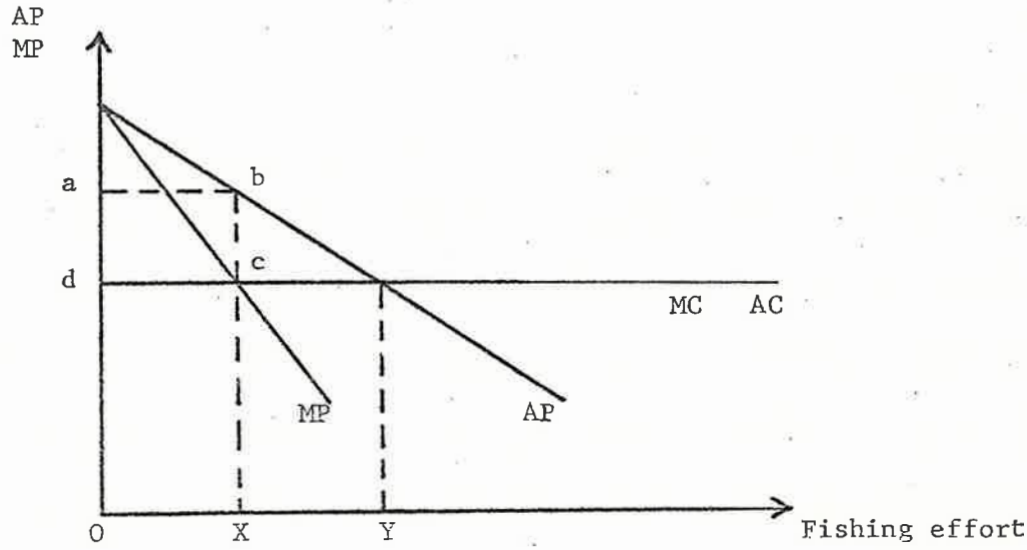
VMP = Value of marginal product

VAP = Value of average product

Consider a body of water to which all fishermen have free access. The haul of one fisherman reduces the expected size of the catch of others. In Figure 4, W represents the wage (and value of marginal product) in activities other than fishing. The number of fishermen in equilibrium will be OB, where the value of average product of a fisherman equals the wage he can obtain elsewhere. This is obviously too many fishermen, because an individual's fishing activity imposes costs on others and thereby generates a marginal social yield lower than the value of marginal product (the wage rate) in other activities. "WE" in Figure 4 may be compared to AB in Figure 1 (the broad road product curve) while the product curves for the fishing activity may be compared to ABC and ABD in Figure 3 (the narrow road product curves). What is required to generate an optimal level of fishing activity is control of entry to the body of water. If this were effected through private ownership, the profit-maximizing firm would hire only OA fishermen making the wage equal to the value of the marginal product. Alternatively a price of admission to the lake equal to DE could be charged. In both cases the efficient level of fishing activity would be reached and the rent maximized, equal to CEDW.

GORDON (1954) used this basic argument to show how the rent is dissipated on fishing grounds for demersal, i.e. bottom-dwelling, fish of relatively non-migratory character, where each fishing ground can be treated as unique. For migratory fish it would be necessary to treat the resource of an entire geographic region as one. Gordon used "fishing effort" as the variable input, and neglected fixed costs in his analysis. For simplicity he assumed a uniformly linear functional relationship between average production and the quantity of fishing effort.

Figure 5



In Figure 5, MC and AC are marginal and average costs. MC and AC are equal because they are assumed to be unaffected by the amount of fishing effort, and they are assumed to include an opportunity income for the fishermen. AP and MP are average and marginal products. OX is the optimum intensity of effort, and the maximum net economic yield is abcd, which may be regarded as the rent yielded by the fishery resource. The rent reflects the productivity of the specific ground, not any artificial market limitation. The rent corresponds to the extra productivity yielded in agriculture by soils of better quality or location than those on the margin of cultivation. But the rent from the fishing ground is dissipated because it is not appropriated by anyone.

The reason for this is that a stable equilibrium is not reached until the average product on each fishing ground is equalized. This means that

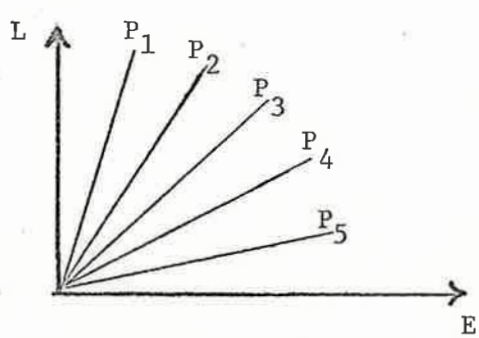
fishing effort is expanded on each fishing ground until average product on each equals the average product on the extensive margin. The yield here is nothing more than operating costs plus opportunity cost of labor. Average product equals average cost, and there is no rent. Average cost is the same for all grounds. This means that the intramarginal grounds also will yield no rent. It is dissipated through misallocation of fishing effort, which is expanded to Y in Figure 5. The optimum is where the marginal products are equal on all grounds and equal to marginal cost, corresponding to Od in Figure 5, with fishing effort OX.

In this case, the marginal fishing ground corresponds in a sense to the broad road where no rent is achievable. Each intramarginal ground then corresponds to a better road with decreasing marginal returns. Gordon assumes that the law of diminishing returns in the pure sense is inoperative in the fishing industry. But the catch of fish increases at a diminishing rate because of the effect of catch upon the fish population.

This assumption is reflected in the "bionomic equilibrium" of the fishing industry in a linear relation between fishing effort (E) and "landings" (L) (total quantity fish taken or "landed" by man, measured in value terms), with one straight line for each population level (P).

$$L = L(P,E)$$

Figure 6



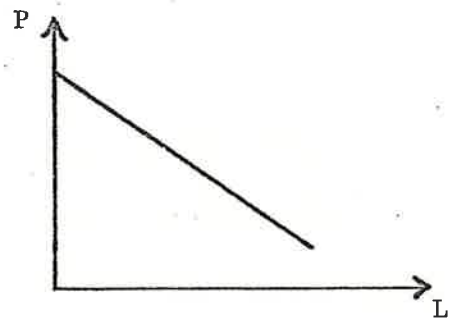
$P_1 > P_2 > P_3 > P_4 > P_5$

It is also assumed that no landings-induced price effects affect the value of landings.

We also have that population is a simple negative function of landings:

$$P = P(L)$$

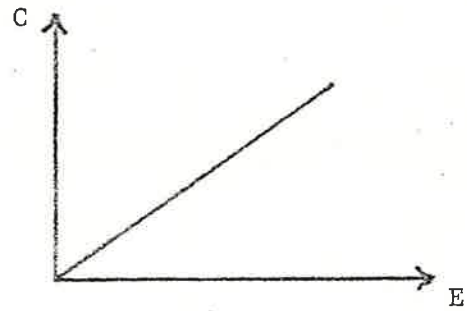
Figure 7



And total cost (C) is assumed to be a linear function of fishing effort:

$$C = C(E)$$

Figure 8



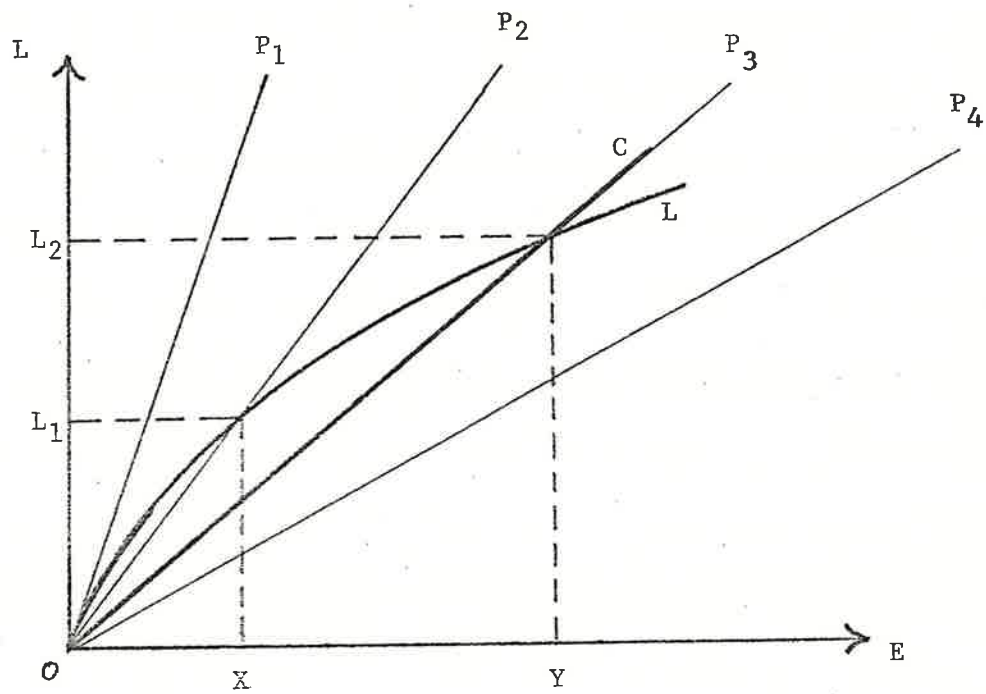
The equilibrium condition for an uncontrolled fishery is:

$$C = L$$

But stable equilibrium requires that either the cost or the landings function be non-linear. This condition is fulfilled by the assumption that population is reduced by fishing (and not fulfilled by the regular law of diminishing returns or increasing costs). When we take this into consideration, we obtain a landings function with steadily diminishing returns (negative second derivative). We may regard the landings function as moving progressively to lower population contours as total landings increase in magnitude. The

curve labeled L in Figure 9 traces out the series of combinations of E, L and P which are compatible with one another in the system:

Figure 9



The total cost function (C) is in Figure 9 measured in terms of landings. It is a linear function of effort.

The optimum intensity of fishing effort is that which maximizes L - C. This is at the point X in Figure 9, where the slope of the landings function equals the slope of the cost function. This will yield OL_1 of landings and the species population will be in continuing stable equilibrium at a level indicated by P_3.

The equilibrium resulting from uncontrolled competitive fishing, where rent is dissipated, is where C = L. This means extension of the

fishing effort to point Y, yielding OL_2 of landings and resulting in a stable population at the level indicated by P_4. Clearly, the uncontrolled equilibrium means a higher expenditure of effort, higher fish landings, and a lower continuing fish population than the optimum equilibrium.

Gordon did not say much about how the problem he presented was to be solved. Mainly he merely stated that:

> Common-property natural resources are free goods for the individual and scarce goods for society. Under unregulated private exploitation they can yield no rent; that can be accomplished only by methods which make them private property or public (government) property, in either case subject to unified directing power. (p. 135)

SCOTT (1955) built on Gordon's article and went on to compare the use of a fishery by competing fishermen with the mode of management that would be most profitable to a "sole owner". "Sole ownership" was not meant to be monopoly, but "merely complete appropriation of all of a natural resource in a particular location". (p. 117).

Scott questions Gordon's assumption that the operating cost function does not have a positive second derivative. Scott says that in the short run this is incorrect; that each fishing boat will experience increasing costs as it attempts to increase its landings. Also, only in the long run, more than one season, will the depletion of the population produce a species of "diminishing returns" effect. In the short run the fish population is one of the fixed inputs and fishermen do not expand their catch indefinitely because they do experience increasing costs in attempting to increase their landings. With fixed equipment and a fixed number of boats there will be some number of landings per boat which has a least cost; if the crew is worked long hours, or the boat is kept running without time for maintenance or repair, the cost per landing will begin to rise. Each boat will increase

its landings until its supply price (marginal cost) is equal to the going price. The "surplus" that might be captured in this situation is the usual quasi-rent, available to each boat by operating at the point where marginal costs are equal to marginal revenue.

Scott concludes that if a sole owner was to take over the fishery there would be no basic change in the exploitation of the fishery in the short run. He would still tend to operate where short-run marginal costs equal price. Though the sole owner would rationally be able to lay off some boats if there was externalities due to crowding and congestion. He might also design his fleet and his transport and packing facilities so as to take advantage of the economies of integration and scale.

Both of the two last points are quite valid in my opinion. We will later see how SMITH (1968) builds crowding externalities into his more complete model. But the questions are as much a case of long run as of short run. In the short run, the opportunity cost of the boats may be very low or zero, and the crowding externalities would have to be quite substantial to justify laying off some boats. And to take advantage of economies of integration and scale seems to be much more relevant for a long-run consideration. Whether the new situation would result in the sole owner using more or less variable factors, and whether his catch would be larger or smaller, is impossible to say. The difference may not be significant, although the productivity of all inputs would almost certainly be higher, since the sole owner has the choice of a wider range of techniques.

But I do think Scott is missing a main point in his argument. Admittedly, Gordon does not discuss at all the difference between short run and long run. And he does not consider explicitly the externalities that enter because no

fisherman has an incentive to husband the resource for future returns. (This is done both by Scott and Smith.) Also, it is quite possible that the cost function of each fishing boat has a positive second derivative due to factors mentioned by Scott. But I think that his argument that the fishing population is one of the fixed inputs within a single season, does not hold and makes him avoid the whole problem of the externalities that is the base for Gordon's agrument. These externalities are of the same type as those of Knight's road case, even though it is not explicitly stated. Gordon does not state that when an additional fisherman enters the intramarginal fishing ground, he imposes a cost on all the fishermen that are there from before; and that it is only in this way that average product for each fishing ground is brought down and equalized with the fishing ground at the extensive margin. Neither does Gordon state that this imposed cost is due to the diminishing of the fish population, which makes it harder for all the fishermen to catch fish. To get the same catch, as earlier, they will now each have to put in more fishing effort. But even though this is not explicitly stated, it is implied in the curved shape (negative second derivative) of the landings function in Figure 9. And it is the same assumption that gives rise to the negatively sloped average and marginal product curves in Figure 5. The increased difficulty of catching fish is in each case implicit in the product curves. By assuming that there is no such increased cost in the short run, Scott finds no externalities other than those due to crowding. And assuming these and scale economies away, he ends up with the same result for the competitive situation as a sole owner would get: equality of marginal cost and marginal revenue, hence efficient use of the resource.

As Gordon relies upon the "diminishing returns" due to reduced stock of fish, Scott relies upon the increasing cost due to long hours and lack of maintenance to explain that the competitive fishery does not expand indefinitely. Gordon assumes no such increasing costs and has a linear total cost function, hence horizontal average cost function (equal marginal cost). But if we let Gordon's cost function only be the opportunity cost of labor (the wage rate in best alternative employment), the increasing costs could be assumed absorbed in the product curves of Figure 5 (or 4), by defining fishing effort to include these costs, and the basic argument for inefficient exploitation would be left unchanged.

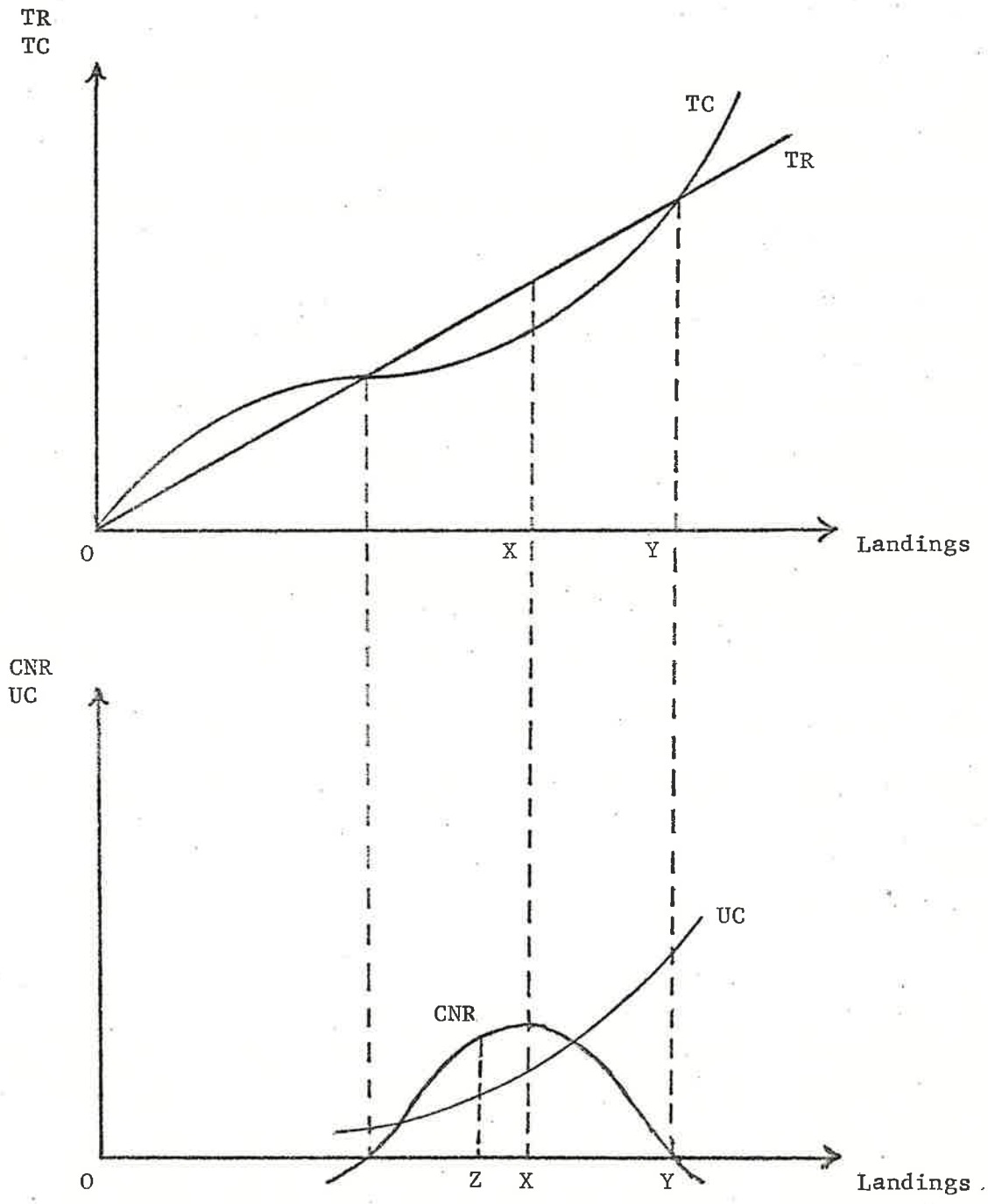
Scott's argument implies that there are no increasing costs in the short run due to diminution of the fish population. This may in fact be true, but it may also be false, and it is wrong of Scott to assume that it is always true. It will only hold where population size is very large relative to the industry. But in such cases, there is reason to believe that "resource stock externalities" would not arise in the long run. The question of whether the size of the stock has an influence on the cost of catching, is in fact an empirical one, and must be determined for each fishery case separately.

But Gordon's argument seems to be mainly concerned with the short run. He does not explicitly consider the long run except saying that the stable long run population will be P_3 or P_4 in Figure 5 for the optimal (sole owner) and inefficient competitive situation respectively. But he has no analysis of the optimal time path to get to this stable equilibrium or whether this equilibrium is optimal taking time into consideration. On the other hand, while missing the point in the short run, Scott has a good point for the long run. He says that the basic explanation for the

inefficiency of competitive exploitation of fisheries is "the inability to control the size of the fish population in the long run". (SCOTT, 1955, p. 2). It is not true that this is the only explanation for the inefficiency, since Grodon's argument may still hold in the short run. Rather, this inability to plan for the future gives rise to another type of externalities in addition to those caused by increased cost in the short run. What is now at stake, is the best use of the factors of production over time, especially the role of the stock of fish as a factor of production. It is not to be concluded without further analysis, that the rational owner of a fishery would even wish to find an "equilibrium" size for the fish population. His most profitable action might instead be to deplete the fishery, gradually, over time; or, alternatively, to build it up over time. As long as the user of a fishery is sure that he will have property rights over the fishery for a series of periods in the future, he can plan the use of the fishery in such a way as to maximize the present value (future net returns discounted to the present) of his enterprise. From the social point of view the "best" use of the fishery and of all other factors over future periods is achieved by allocating outputs and outlays over time in accordance with the current rate of discount.

The basic point of view may be illustrated by Figure 10:

Figure 10



CNR = Current net revenue
TR = Total revenue
TC = Total cost
UC = User cost

The diagrams indicate the situation of a fishery in one season. Landings is expressed in physical quantities. It is assumed that the landings have no effect on selling price, and the shape of the total cost curve indicates increasing costs in the short run.

The competitive equilibrium will occur where TC = TR, at an amount of landings equal OY. The short run optimal amount of landings is OX, where TC is parallel to TR, that is, where marginal cost equals price. However, if the catch today has an influence on the population and so on the catch tomorrow through the productive power of the resource stock, the sole owner will wish not only to maximize current returns, but also to arrange for the optimum series of landings through the ensuing future periods. He will try to maximize the present value of his property. He must investigate the effect of his marginal current output on the present value, that is, find his marginal user cost. Then he will fix current output where marginal current net revenue is equal to marginal user cost. This output is OZ in Figure 10, where the total net revenue curve is parallel to the user cost curve. The user cost curve shows the effect of succeeding units of current output on the net present value of the enterprise. The greater the rate of interest (or time preference), the lower the valuations put on landings in the future, and the lower the user cost.

In Figure 10, marginal user cost is pictured as being positive. This means that increased current output reduces the net revenues that can be earned in future periods. The user cost curve slopes upward, and marginal user cost will equal marginal net revenue at less than the maximum total net revenue. Sole ownership will now result in still greater reduction of optimal output.

But the marginal user cost may also be negative, that is, increased output today will increase net revenues to be earned in the future. The user

cost curve would slope downward, and optimal current rate of output would be larger than that which yield maximum current return. It may even be larger than the equilibrium position of the competitive situation, (at Y in Figure 10).

In the case of a nonzero user cost, we have an unregulated external effect in the competitive situation. Each fisherman's catch today will affect the revenue (or cost) of every fisherman in the future. His own revenue will also be affected, but only as a result of a change in the average. This may enter his decision process. But the marginal effect of his catch will be much larger, and this will not enter his decision process. Even the average consideration may not enter if the fisherman does not feel any certainty of receiving any portion of the possible result of his action. For example, if he restricted his catch somewhat to raise the average productivity (or lower average cost) in the future, he may expect that other fishermen will increase their catch today and thereby offset his action.

It seems to me that Gordon's and Scott's arguments are basically the same. The difference is that Gordon does not distinguish between short run and long run, while Scott focuses on the long run. If we look at Gordon's argument only concerning the short run, using Scott's terminology, we may say that the reason for the inefficiency in the competitive situation, is that each fisherman does not consider the marginal user cost of his catch in the current season. He does not consider how the marginal productivity falls, but considers only the fall in average productivity due to his catch and consequent reduction of the fish stock in the current season. But Gordon does not allow for the possibility of a negative marginal user cost, which indicates that he actually is only concerned with the short run.

Though, Gordon's analysis will also hold for the long run if the long run marginal user cost is positive. Scott, on the other hand, denies the possibility of a positive marginal user cost in the short run, but considers both positive and negative marginal user costs in the long run. These will not enter the decision process of each fisherman in a competitive situation. Hence, we again have a clear case of a depletable externality. The catch of one fisherman reduces or increases the expected size of the catch of himself and others in future periods, but this does not affect his decision of how much to catch in the current season. The result of individual maximizing behavior in this setting may either be an over-optimal <u>or</u> under-optimal level of fishing activity. But a sole owner could internalize both the short run and long run depletable externalities and reach the optimal level. The short run externality could also be corrected by using a tax per unit catch equal to the difference between average and marginal productivity at the optimal level of fishing effort. The long run externality could be corrected by using a tax (or subsidy) equal to the marginal user cost (of future periods) at the optimal level, the user cost being the effect of increasing the current catch on net present value of total revenue of the fishery.

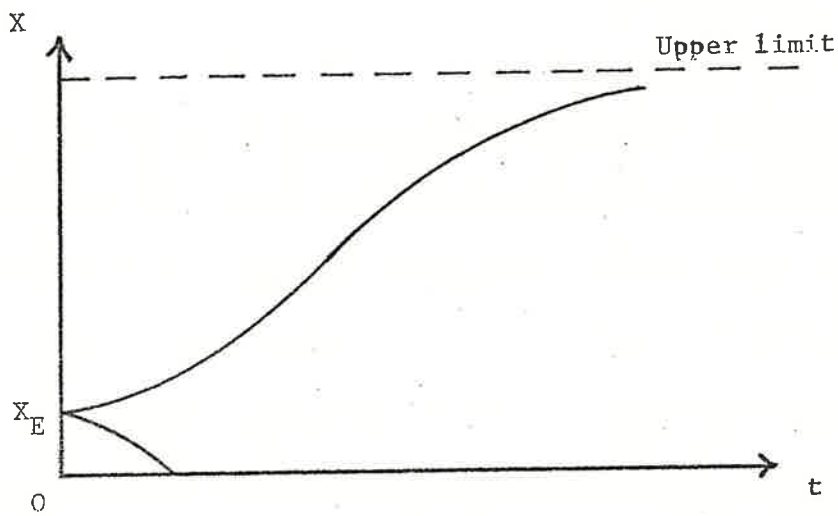
If we do regard Gordon's argument to only consider the short run, there really is a significant difference between his and Scott's arguments. This is due to the dual role of the stock of fish: The size of the stock may make a difference for the cost of catching it, but it also makes a difference for the productive power of the resource and hence for the "flow" and stock of the resource in the future. Scott's long-term user cost may include both of these effects, even though he did not explicitly point to this in his article. In the short run however, it is only the increased cost of a reduced stock today that is in question.

Both Gordon and Scott wrote about the effect of "fishing effort" and catch on the fish population and the consequences of this effect, which was an inefficient use of the fishery resource in unregulated competitive exploitation. But they did not try to put their results into a mathematical, more stringent form. Neither were they very explicit about the different variables, such as fish population mass and growth, vessel catch rate, and investment. But all of this was improved considerably through articles by SMITH (1968, 1969), building on the basic contributions by Gordon and Scott.

SMITH (1968) developes a general theory of production from natural resources. A single model of an industry is used to describe the process of recovery from such technologically diverse resources as fish, timber, petroleum, and minerals. Recovery from each of these resources is seen as a special case of a general model, depending upon whether the resource is renewable, and on whether there are significant externalities in the production.

Fish is a renewable, or flow, resource. It is capable of regeneration and man consumes a flow of the resource. The mass growth of a species will depend upon certain internal biological characteristics of the species and on its environment. For analytical purposes in our context we may abstract to the general case where the population grows in a given environment at a rate dependent only on the size of the population. The size of the bio-mass, X, may be expressed as a function of time (t):

Figure 11

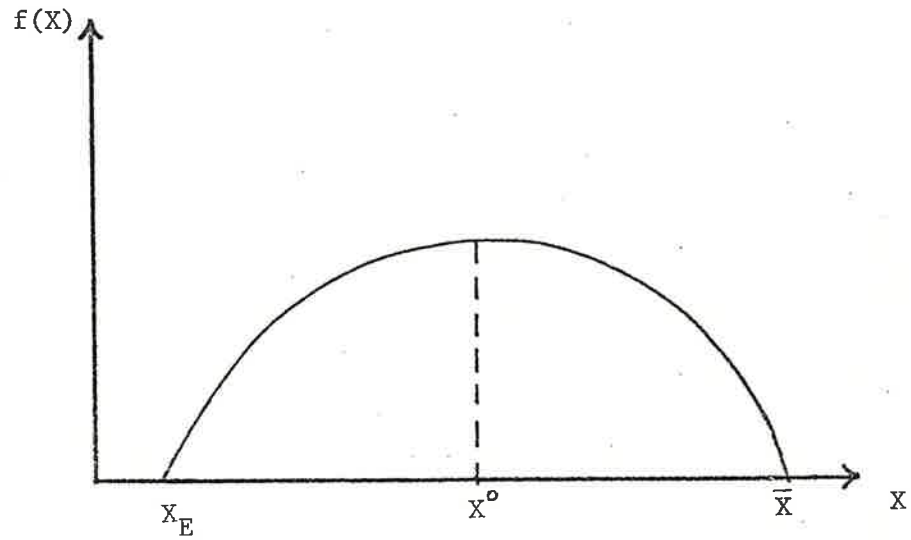


In some cases, a critical level of population is reached (X_E) below which growth will be negative until population is zero.

The absolute rate of growth, $\dot{X}$, may be expressed as a function of X: $\dot{X} = \frac{dX}{dt} = f(X)$. It will have the "inverted U" properties shown in Figure 12. It will have a maximum corresponding to the population X^o which produces the largest sustainable yield or net rate of growth. And it will be bounded by two zero values: at maximum population $\overline{X}$, and at extinction level, X_E.

These ideas have been expressed in a particular function sometimes called the Verhulst-Pearl logistic law of growth. This has been used for analyzing halibut (CRUTCHFIELD and ZELLNER, 1962), yellowfin tuna (SCHAEFER, 1967) and other species (BEVERTON and HOLT, 1957).

Figure 12



Now assume that recovery from a given resource is affected by K homogeneous firms or units of capital (vessels), each producing an output at rate x. Total industry output is then Kx, where both K and x are, in general, variables. With extraction (fishing) activity, we then have:

$$\dot{X} = f(X) - Kx$$

Here we assume no interaction between total harvest and the growth properties of the population mass. K, x, and X are each a function of time.

Smith focuses on the cost function of each firm, rather than on the production function. The most natural general hypothesis about total operating cost for the individual fisherman requires it to be an increasing function of the vessels catch rate, x, but a decreasing function of fish population, X. The latter specification is implied if it is the case that when there are more fish of a given species, they are easier to catch. Also, total operating cost may be an increasing function of the number of vessels. If the fish population is highly concentrated, the efficiency

of each boat may be lowered by congestion over the fishing grounds. The general cost function for the fishing firm is then:

$$C = \phi(x,X,K)$$

where:

$$\frac{\partial C}{\partial x} > 0$$

$$\frac{\partial C}{\partial X} \leq 0$$

$$\frac{\partial C}{\partial K} \geq 0$$

Externalities enter because no individual competitive fisherman has control over population size or the number of vessels as private decision variables, yet they enter as a parameter in each fisherman's cost function. When $\frac{\partial C}{\partial X} < 0$, recovery costs exhibits what Smith calls "stock externalities". This is the kind of externality that is implied in both Gordon's and Scott's arguments. Scott also mentions the "crowding externalities" which recovery costs exhibits when $\frac{\partial C}{\partial K} > 0$. And the assumption that $\frac{\partial C}{\partial x} > 0$ is equivalent to the increasing costs that Scott used as an argument for the achievement of efficient exploitation by competitive fishermen in the short run.

Smith goes on to characterize the competitive recovery process in any extractive industry by a system of three behavior equations describing the interaction of the resource, individual firms, and the industry:

<u>Resource</u>: $\dot{X} = f(X) - Kx$ (I)

This describes net growth of the stock as a function of stock size and industry output. In a steady state situation, we have $\dot{X} = f(X) - Kx = 0$.

<u>Firm</u>: $\frac{\rho(Kx)}{Kx} - \frac{\partial C}{\partial x} = 0$ (II)

This is the profit maximizing condition when p(Kx) is total revenue, $\frac{\rho(Kx)}{K}$ is revenue per firm and $\frac{\rho(Kx)}{Kx}$ is price (perceived as a given constant). The firm's pure profit function is:

$$\pi = \frac{\rho(Kx)}{K} - C(x,X,K)$$

where C(x,X,K) is treated as a function only of the private control variable x.

<u>Industry</u>: $$\dot{K} = \delta\left[\frac{\rho(Kx)}{K} - C(x,X,K)\right] \qquad \text{(III)}$$

$\dot{K}$ is the rate of change in number of firms in the industry. New firms are assumed to be attracted into the industry when $\pi>0$ while producing firms are driven out when $\pi<0$. $\delta>0$ is a behavioral constant for the industry. If selling price is constant, $p = \frac{\rho(Kx)}{Kx}$ = constant, and we have a steady state situation, we may write the behavioral equations:

$$\dot{X} = f(X) - Kx = 0 \qquad \text{(I')}$$

$$p - \frac{\partial C}{\partial x} = 0 \qquad \text{(II')}$$

$$\dot{K} = \delta[px - C(x,X,K)] \qquad \text{(III')}$$

The articles by Gordon and Scott emphasized the advantages of unified management as distinct from the unregulated decentralized exploitation of the resource. The basic reason is that centralized management permits all the social costs of production to be borne privately with the result that the private producer has the incentive to manage the resource in the interest of society as well as his own. To see how these results follow using the competitive model of equations I', II', and III', it is necessary to develop a contrasting model of centralized management.

We assume steady state equilibrium, $\dot{X} = f(X) - Kx = 0$ (I''). Under centralized management, x, X, and K will all be decision variables subject to control, in the interest of profit, by the sole owner. His profit function will be $\bar{\pi} = pKx - KC(x,X,K)$ which is to be maximized with respect to x,X, and

K, subject to $\dot{X} = f(X) - Kx = 0$. The Lagrangean equation is thus:

$$L = pKx - KC(x,X,K) + \lambda[f(X) - Kx]$$

and the first order conditions for an interior maximum can be written:

$$\frac{\partial L}{\partial x} = pK - K\frac{\partial C}{\partial x} - \lambda K = 0$$

$$\Rightarrow \quad p - \frac{\partial C}{\partial x} = \lambda \qquad \text{(II'')}$$

$$\frac{\partial L}{\partial K} = px - K \cdot \frac{\partial C}{\partial K} - C - \lambda x = 0$$

$$\Rightarrow \quad p - \frac{C}{x} - \frac{K\frac{\partial C}{\partial K}}{x} = \lambda \qquad \text{(III'')}$$

$$\frac{\partial L}{\partial X} = -K\frac{\partial C}{\partial X} + \lambda\frac{df(X)}{dX}$$

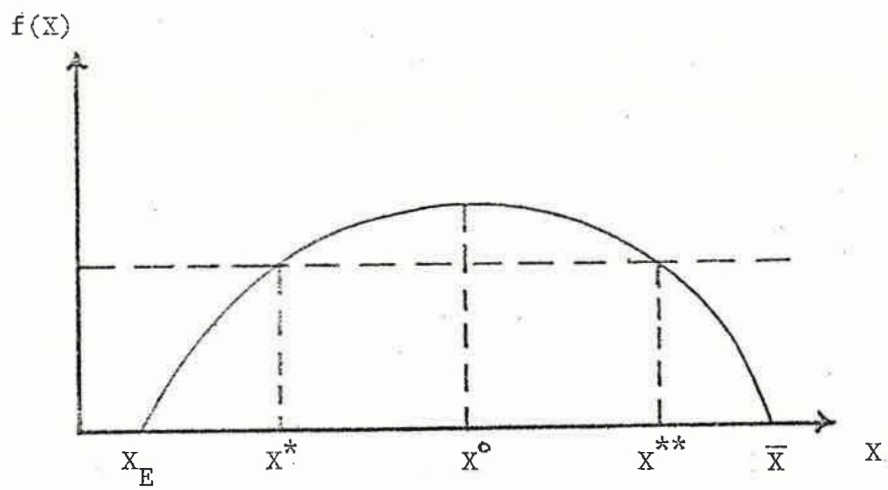
$$\Rightarrow \quad \lambda = \frac{K\frac{\partial C}{\partial X}}{\frac{df(X)}{dX}} \qquad \text{(IV'')}$$

The Lagrange multiplier, λ, is the marginal profitability of the total fleet catch or yield of the fish mass. Condition (II'') requires the marginal profitability of increasing catch by intensive use of the fleet (i.e. by increasing x) to be equal to the marginal profitability of total fleet catch, λ. Condition (III'') requires marginal profitability of the catch from fleet expansion to equal λ. And $K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ is the marginal external or social cost of the fleet catch. An increase in catch lowers the fish mass and this imposes fishing costs external to the individual boats. This is the external costs causing dissipation of rent in Gordon's argument if we take it to consider the long run, and it is what Scott refers to as user cost.

Since $\frac{\partial C}{\partial X}$ is negative while $\frac{df(X)}{dX}$ may be negative or positive, the question arises as to whether a maximum can occur with negative marginal

social cost. Smith says that a global maximum cannot occur at an X^* such that $\frac{df(X^*)}{dX} > 0$. Suppose we have equations (I'') - (IV'') satisfied by a point (x^*, X^*, K^*), with $\frac{df(X^*)}{dX} > 0$. Then we know from the properties of $f(X)$, that there is an $X^{**} > X^*$ such that $\frac{df(X^{**})}{dX} < 0$, and $K^* x^* = f(X^*) = f(X^{**})$. But since $\frac{\partial C}{\partial X} < 0$, $C(x^*, X^*, K^*) > C(x^*, X^{**}, K^*)$. It follows that the point (x^*, X^{**}, K^*) satisfies the system and yields a greater profit. Hence, $\frac{df(X)}{dX} < 0$ and $K\frac{\partial C}{\partial X} \Big/ \frac{df(x)}{dX} > 0$ in (IV''). This again means that in the optimal situation under unified management, the stock of fish will always be kept larger than X^o:

Figure 13



Under competitive harvesting $K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ is a social cost which does not affect the firm behavior, but this social cost is internalized when property rights are vested in a central manager-owner who adjusts his operations according to (II'') and (III'') to account for these costs.

Similarly will the central manager adjust for the effects of boat crowding over the fishing ground. In the equation leading to (III'') we have:

$$px - K\frac{\partial C}{\partial K} - C - \lambda x = 0$$

Here, px is the gross marginal revenue from an additional vessel, C is the long run direct internal cost, while $K\frac{\partial C}{\partial K} + \lambda x$ is the long run marginal external social cost of operating an additional vessel. An addition to the fleet causes external crowding cost at the rate $K\frac{\partial C}{\partial K}$, and external fish scarcity cost at the rate λx.

Let us compare (II') and (III') from the decentralized competitive system with (II'') and (III'') from the sole owner case:

$$p - \frac{\partial C}{\partial x} = 0 \qquad \text{(II')}$$

$$p - \frac{\partial C}{\partial x} - \lambda = 0 \qquad \text{(II'')}$$

$$px - C = 0 \qquad \text{from (III')} \qquad (\pi = 0 \text{ in equilibrium})$$

$$px - C - K\frac{\partial C}{\partial K} - \lambda x = 0 \qquad \text{from (III'')}$$

In both cases we have assumed $f(X) - Kx = 0$, the stationary state. The two systems differ only in that the sole owner perceives a unit catch cost, $\lambda = K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ and an annual boat cost, $K\frac{\partial C}{\partial K} + \lambda x$, which is not incurred by the decentralized competitive fisherman. Theoretically then, the problem of regulating the competitive recovery can be stated as one of imposing these unperceived social costs on the industry. The partial equilibrium solution to the problem of regulating is to levy an extraction fee $U = K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ per unit of catch, plus an annual license fee $L = K\frac{\partial C}{\partial K}$ on each fishing vessel. Profit after taxes to each competitive fishing vessel is then: $\pi^* = px - C(x,X,K) - L - Ux$. Each fisherman chooses x to maximize π^*, and vessels enter the industry as long as $\pi^* > 0$. The equilibrium

conditions then are $\frac{d\pi^*}{dx} = 0$, which gives $p - \frac{\partial C}{\partial x} - U = 0$ (II''') and $\pi^* = 0$, which give $px - C - L - Ux = 0$ (III'''). Now, (II''') and (III''') are identical to (II'') and (III'') for centralized management provided that the regulating authorities are able to fix $U = \lambda = K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ and $L = K\frac{\partial C}{\partial K}$ at optimizing values satisfying (II''), (III''), and (IV'').

The expression $K\frac{\partial C}{\partial X} \Big/ \frac{df(X)}{dX}$ is the marginal external or social cost of the fleet catch. But to me it requires more explanation than given by Smith. $\frac{\partial C}{\partial X}$ is the annual marginal cost of increasing catch by one unit through the diminution of the stock. But since this cost is experienced by all fishermen, we have to multiply by K. This is the short run external cost which we may interpret Gordon's argument to have considered. This cost represents the sacrificed marginal product of a unit of stock. But it would have been earned in all subsequent periods. Taking this into consideration, we obtain the long run user cost that Scott was concerned about. To see that this is what Smith's expression gives, we must view the denominator as equivalent to a rate of discount. The annual flow of product from the stock is f(X), and $\frac{df(X)}{dX}$ indicates the effect of a unit change in X on this flow. This derivative can be viewed analogous to a rate of interest showing the productive power of the stock to increase the flow of product per unit time in relative terms:

$$\frac{df(X)}{dX} = \frac{d\left(\frac{dX}{dt}\right)}{dX} = \frac{d\left(\frac{dX}{dt}\right)}{dt} \cdot \frac{dt}{dX} = \frac{1}{f(X)} \cdot \frac{df(X)}{dt}$$

But the dual production role of the stock of fish, that the natural rate of growth of the stock depends on the size of the stock and the stock contributes a productive service to the catch activity, is not revealed

by Smith's exposition. But this point is made clear by HERFINDAHL and KNEESE (1974, p. 163) in an adaptation of BROWN's (1974) model for management of a common property resource. Here, the approach is from the production side rather than from the cost side. The total production function for the fishery gives catch as a function of fish population and capital services: $x = G(X,K)$. With fishing we have a steady state solution when

$$f(X) - G(X,K) = 0$$

And as in Smith's case, since we assume a steady-state solution, it suffices to consider the optimum way to handle a single period since all others will be like it. Thus we seek to maximize $pG(X,K) - wK$ subject to $f(X) - G(X,K) = 0$, where p is the constant price of the product and w is the price of one unit of capital service. The Lagrangian expression is:

$$L = pG(X,K) - wK + \lambda\left[f(X) - G(X,K)\right]$$

which gives:

$$\frac{\partial L}{\partial K} = p\frac{\partial G}{\partial K} - w + \lambda\frac{\partial G}{\partial K} = 0$$

$$\Rightarrow \quad w \Big/ \frac{\partial G}{\partial K} = p - \lambda \qquad \text{(A)}$$

and:

$$\frac{\partial L}{\partial X} = p\frac{\partial G}{\partial X} + \lambda\left[\frac{df(X)}{dX} - \frac{\partial G}{\partial X}\right] = 0$$

$$\Rightarrow \quad (p - \lambda)\frac{\partial G}{\partial X} + \lambda\frac{df(X)}{dX} = 0 \qquad \text{(B)}$$

In this last expression, B, the mentioned dual role of the stock of fish is clearly indicated. In the static case, the stock is adjusted so that its value of marginal product in catching fish is just balanced by the value of the effect of stock on natural growth. The productivity of the stock in catching is valued, not at p, as would be the case with a piece of land used to produce wheat, but at $(p - \lambda)$. The subtraction of λ indicates that a unit of caught fish had a value in bringing about growth

of the stock of fish. The favorable effect on production of a unit increase in stock must be exactly offset by the unfavorable effect on natural growth, hence $\frac{df(X)}{dX}$ must be negative. This is the same result as Smith reached, indicating that in the optimal position the stock will be kept larger than X^o.

But the result that the optimal stock size is always larger than X^o, the stock size that gives maximum natural growth, is based on the assumption of zero costs associated with getting to the steady state, the position that will be maintained for all time. Due to this assumption, the interest rate does not appear in the models presented, except in Scott's concept of user cost. In a more realistic view of the problem than Smith's steady state solution, one must deal with optimizing the evolution of the system over time. Any action taken at a certain point in time, finds a certain stock in existence. The problem is how to go from period to period so as to maximize net returns to society, how to find the optimum set of time paths for the variables. Among others, this is done by QUIRK and SMITH (1969) and BROWN (1974).

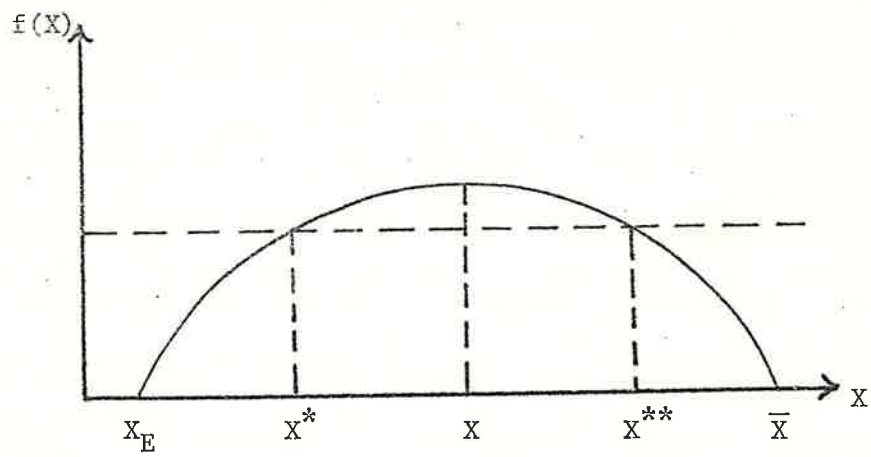
Solution of this type of problem requires the use of calculus of variations, optimal control theory, or dynamic programming. But in this paper I will describe the nature of the problem and its solutions in words.

The rate of discount tends to encourage earlier consumption and to push outlays for capital services toward later dates. The value of the stock of fish must be balanced against its value if consumed. Proper account must also be taken of the "natural productivity" of the stock, that is, the natural time rate of increase in the stock is related to the size of the stock.

The initial position for the start of a unified management program may be low initial levels of the stock resource. This condition arises

when valuable natural resources in the past have been regarded as common property by their users. The marginal stock resource value, λ, will be relatively high, maybe greater than the market price of the product. Then there should be no extraction for a period until the stock has increased to a point where the absolute time rate of growth is higher. Though it may also happen that the marginal value of a larger stock in production is not very great, at a stock size smaller than X^o. Then it may not pay to forego the consumption that would be necessary to increase the stock to the size greater than X^o which yields the same rate of natural growth. Although it is true that extraction costs fall with increasing X, they may not fall sufficiently fast to warrant waiting while stocks build up.

Figure 14



On the other hand, if we start at a large stock, say $\overline{X}$, it will pay to reduce stock to a point where growth is larger. But if the value of

stock in production is low, it may be optimal to go to X^* to the left of X^o, rather than stopping at X^{**} in Figure 14. The present value of increased costs of production in future periods, because of lower stock, may be more than offset by the present value of reductions in stock as consumption.

Clearly, there are also fish resources for which it is never profitable to harvest because unit extraction cost is higher than the price consumers are willing to pay. This may also be accounted for in Gordon's model in Figure 5. That is when the cost curve is everywhere above revenue for a particular species. But this model cannot handle the situation in which a species may be depleted to the point of extinction. And this may well be sound economically if the discount rate is large enough, the biological growth rate low enough for any level of X, and the factor cost small enough. The blue whale may be an example of this case if society believes the loss of this species is relatively low.

The conclusions that the optimal level of stock may be smaller than X^o, is contrary to the conclusion reached by Smith (who concluded that the optimal level is always to the right of X^o, see p. 45). Smith's conclusion cannot be reached in a dynamic context because there is an opportunity cost in waiting for larger stock levels. BROWN (1974) concludes that, "The static treatment and solution of an externality problem which is inherently dynamic, generally will lead to prescriptions which cause social losses". (p. 171). In Smith's article the restriction of $\dot{X} = 0$ is binding in the dynamic formulation, hence costly.

Even though the optimal size of the stock may differ in the static and dynamic cases, the characteristics of the externalities are the same.

Hence, also the policies necessary for regulating a decentralized competitive system to behave optimally are the same. Efficient use of the resource can be achieved if the management agency enunciates two pricing policies, one which reflects the scarcity value of the resource stock and another one designed to capture the cost of congestion. It is necessary to levy a charge per unit extracted, equal to the value of the marginal product of the stock. And the congestion externality may be accounted for by charging a tax for the use of each unit of the variable input factors.

CONCLUDING REMARKS

In the first section of my paper, I tried to describe and clarify the general concept of external effects or externalities. From my presentation, it may seem as the concept is clear and generally agreed upon. This is not so even today, and the historical development has shown a good amount of confusion of terms and concepts. The term "external economies or diseconomies" began, perhaps, with Marshall, and it was frequently used in the 1930's and 1940's for the derivation of cost and supply curves. But this discussion considered what is today classified as pecuniary external effects as opposed to technological. BATOR (1958) proposes to interpret the concept so broadly that it includes most major sources of what he calls "market failure". He even includes in this category cases of increasing returns to scale resulting in "natural monopoly". On the other hand, HERFINDAHL and KNEESE (1974) separates what they call external effects from the market failure that occur due to public good characteristics of a good. CHEUNG (1970) is so frustrated with the whole concept that he wants to discard it entirely. He wants to approach the problem through the analysis of contracting and concludes that:

> The concept of "externality" is vague because every economic action has effects; it is confusing because classifications and theories are varied, arbitrary, and ad hoc. For these reasons, theories generated by the concept of "externality" are not likely to be useful.

In this perspective the discussion of externalities by BAUMOL and OATES (1975) was clarifying. Though, they state that "we do not delude

ourselves that this discussion will be the last word on the subject". But their presentation of undepletable and depletable externalities was clarifying to me.

I do not agree with Cheung that the concept of "externality" is useless. As I have shown in my second section of the paper, the concept, as presented in the first section, may be useful in explaining economic inefficiencies in unregulated competitive marine fisheries and similar "common property" natural resources. The theory of externalities here also reveals what actions may be taken to correct the inefficiencies.

We saw that GORDON's (1954) argument about the dissipation of rent from the fishery, is basically the same as in KNIGHT's (1924) exposition of PIGOU's (1920) case of good and bad roads. In both cases we have a negatively sloped average product curve being the base for decisions by the individual decision-makers in a "common property" situation. This leads to an inefficient state of exploitation since it is the marginal product (in value-terms) that should be equalized to the marginal cost. The externality enters because the individual decision-maker does not consider the costs his action imposes on the other economic entities. But Gordon is not very explicit about the nature of these costs. He merely states that the reduction of the stock of fish will produce a production function with steadily diminishing slope. If he had been more explicit about the biological and technological assumptions underlying this result, we might have avoided the confusion created when SCOTT (1955) discarded Gordon's argument and brought in the concept of a long term user cost, as the reason for inefficient use of the fishing resource.

Seemingly there was a disagreement between Gordon and Scott. But in view of later developments of the theory, it is clear that they basically are in agreement. Gordon's diminishing returns is in the long run due to the same factors causing a positive user cost in Scott's argument. Whether there is a cost associated with diminishing the stock within one season is an empirical question rather than a theoretical. But Scott's argument brings in the other aspect of the dual role of the stock of fish, namely its influence on the productive power of the stock. And he also brings in the dynamic question of how to allocate fishing effort over time in order to maximize the net present value of the fishery. This is an important point to bring up, but it was not until many years later that this was brought into more formal models of the fishery. And SMITH (1968) was still theorizing on the basis of a steady state solution. But in the inherently dynamic situation of the fishery, this must lead to prescriptions which cause social losses, as clearly shown by BROWN (1974). But Smith's article contributed considerably to clarify the role of externalities in the production from "common property" natural resources and how they may be corrected by a unified management.

However, the main weakness of the presented theory is that it is relatively sterile for real world considerations. At this level of abstraction, the question of the form of administration is left quite open. The solutions implied by general theory are significant in as much as they suggest the broad nature of the necessary means. But they contribute little toward the "specification of the required institutional mechanisms, the feasibility of such schemes, the attendant equity considerations, or the relative social cost of implementing the schemes". (STEVENS, 1967, p. 169). We do not want to adjust for externalities regardless of cost.

It is not possible to be of much help in policy formulation unless analysis is combined with studies of how various kinds of institutions (firms, markets, taxes, regulations) actually work in practice. We need better models for predicting the behavior of fishing firms in response to new parameters. Research which enables us to gain new insight into the motivations and decision strategies of common property users will be of value to decision makers.

The discussion in section two indicated clearly that the external diseconomies associated with the exploitation of common property resources can be overcome only by bringing these effects into the consideration of a unified management with complete control of the asset. Some assets, such as ocean fisheries, occur on an immense scale, and it is a very real problem to know whether the efficiency gained from unified management provides social gain sufficient to offset the possible dangers of creating some immense role-ownership organization. This problem is barely touched upon in the theory and "assumed away" by Gordon, Scott and Smith by assuming no monopoly powers to occur. But it may not be possible to centralize ownership without at the same time giving the single owner monopoly control over the total supply of resource services. Still, this complication would not lead to any basic change in the analysis of the occuring externalities. They would still be the same. But the possible social cost of having a monopoly would have to be balanced against the value of correcting the externalities.

Another real world problem that must be considered in the theory of fisheries, is the international aspect. Even within a single political jurisdiction such as the United States, it has proven to be a formidable task to set up a unified administration of common property resources.

And in the case of marine fisheries, international conflicts of interest make the problem almost unmanageable. Non-coastal fisheris exist where no political unit has jurisdiction. In the case of migratory fish, several jurisdictions may be involved, or there may be movement between an unowned area and a political jurisdiction. Economic analysis of such situations is only part of their "solution" but it is an essential part if only to prevent the adoption of proposals based on absurd implicit bio-economic models.

It is also likely that the theoretical formalization has abstracted from other essential realities of fishery situations; realities that could have been included in the models and shown some other significant externalities than the "stock" and "crowding" externalities considered in this paper. The fishery must be recognized as a complex ecological system wherein the amount, quality, and timing of both inputs and outputs may affect each other strongly and in a complex manner. Each harvesting action sets off ripples of reactions over a broad region and over a long time span, among both older and younger generations within each stock, and between stocks of fishes and other maritime life. When a vessel catches fish, the reactions and repercussions felt by other vessels then or at other times are quite likely both more numerous and diverse than the literature has so far suggested. The growth function of the stock of fish is certainly far more complex than the one indicated in this paper. One factor subject to regulation is net size, which SMITH (1969) actually has incorporated in his model. This factor can be of great importance in the natural dynamics of the system since it can have a very important effect on the age distribution of the fish.

Biological systems are complex. It is difficult to know what characteristics are relevant for management, and even if these are known, the problem of estimating the parameters of the system is formidable. So, even if we know that a tax should be levied on each unit of fish caught and on each vessel entering the fishery, the cost of estimating the correct tax may be very high. Still, simple cases serve to reveal some of the important economic considerations, and economists may like to remind themselves that the pursuit of the ideal is the enemy of the better. Grossly mismanaged situations exist in many fisheries (see CHRISTY and SCOTT, 1969), and a roughly calculated tax is likely to be superior to not imposing a tax at all -- or to procrastinating indefinitely while engaged in research to refine data and methods in the attempt to produce an ideal tax.

The tax may and should be adjusted over time. If the observed results of the tax seem unsatisfactory, it may be changed. In any case, as the variables determining the "shadow price" of the fish change over time, the tax should be changed. The price of fish must for example be made to vary with the type of fish, its size, when and where it is caught, and what fish are caught with it. The appropriate shadow price will be dependent on the particular historical circumstances as well as the future dynamic paths to be followed. Not only will a single set of static prices be required, but a set of future prices should also be calculated. As circumstances change, or random elements enter the picture, these prices will have to change again. The central agency will have to decide on the frequency with which taxes or prices are changed -- a decision about how to use and generate information about the variables of the underlying conditions.

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