DOMESTIC AND FOREIGN EFFORT APPLIED TO A FISH STOCK: GETTING THE MOST OVER TIME, FOR A CHANGE

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Discussion Paper No. 99

May 1983

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Discussion Paper No. 99, May 1983
Published by the Center for Research on Economic Development
University of Michigan, Ann Arbor, Michigan, 48109, U.S.A.

ABSTRACT

This paper examines key implications of situations where a fish stock is exploited both by vessels from a proprietary nation and foreign units. In terms of rent maximization and capture through taxes on foreign effort or catch, the price received for the fish by foreigners compared to its domestic value is all-important. This also largely determines the domestic/foreign mix choice.

Two main dynamic options for moving from an open-access situation to one of rent maximization, still with domestic and foreign units, and their implications under various discounts rates, are discussed in the second part of the paper.

RESUME

Ce rapport examine les facteurs-clé des situations dans lesquelles la pêche est exploitée par des bateaux provenant d'une nation littorale et des pays étrangers. En ce qui concerne la maximisation de la rente et la perception des taxes sur l'exploitation étrangère de la pêche, les prix perçus les étrangers par rapport à la valeur locale des poissons vendus est d'une importance primordiale. Ceci influe largement sur les décisions concernant le degré d'exploitation par les bateaux nationaux et étrangers.

La deuxième partie du rapport présente deux options dynamiques pour remplacer l'accès auvert par un système de maximisation de rente. Seront examinées les implications de ce dernier système, toujours exploité par des unités divers taux d'actualisation.

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LIST OF SYMBOLS

- a - marginal cost
- AC - average cost
- AR - average revenue
- $\bar{D}$ - fixed level of domestic fishing
- E(t) - level of fishing effort at time t
- E_o - initial open-access level of fishing effort
- E* - rent-maximizing level of fishing effort
- F* - rent-maximizing level of foreign fishing effort, domestic and foreign dockside values of catch being equal
- F*' - rent-maximizing level of foreign fishing effort, domestic dockside value of catch less than foreign dockside value of catch
- P - domestic dockside value of catch
- P' - foreign dockside value of catch
- r - social discount rate
- TC(t) - total cost of fishing effort at time t
- TR(t) - total revenue from catch at time t
- T_c^* - tax rate on foreign catch that captures the entire foreign rent, where domestic and foreign values of catch are equal, and levels of effort and stock are rent-maximizing
- $T_c^{*'}$ - tax rate on foreign catch that captures the entire foreign rent, where domestic value of catch is less than foreign vlaue of catch, and levels of effort and stock are rent-maximizing
- T_e^* - tax rate on foreign effort that captures the entire foreign rent, where domestic and foreign values of catch are equal, and levels of effort and stock are rent-maximizing
- $T_e^{*'}$ - tax rate on foreign effort that captures the entire foreign rent, where domestic value of catch is less than foreign value of catch, and levels of effort and stock are rent-maximizing
- X(t) - stock level at time t
- $\dot{X}(t)$ - time derivative of stock level at time t
- X_o - initial open-access stock level
- X* - rent-maximizing stock level
- α - natural rate of population increase
- γ - catchability coefficient
- π - net rent from fishery

INTRODUCTION

The economic inefficiencies associated with the common-property use of a fishery are well documented in literature containing increasingly extensive and sophisticated bioeconomic models of stock management. These models incorporate, for example, demand elasticity for the output, income distribution effects, interspecie relationships, and optimization over time (see Hartwick, 1979; Quirk and Smith, 1969; and Turvey, 1964). Several authors have also considered the political aspects of international management efforts (see Copes, 1979; Crutchfield, 1979; and Anderson, 1975); the issue of locating and reaching an optimum economic yield in an international fishery has also been addressed (Anderson, 1975).

It appears that under the new Extended Economic Zones (EEZ) regime, great opportunities exist for a change from open-access to controlled effort in fisheries shared by a coastal state and foreign fishing fleets. The purpose of this paper is to outline a model for such a fishery, and to examine the implications of a rent-maximizing policy from the point of view of the coastal state.

BACKGROUND

From the mid-1940's to the late 1960's, world production of fish rose very consistently and rapidly by an average 6 percent per annum. This was followed throughout the 1970's by a period when no further notable increase of world fish production took place, in spite of the continuing increase in the amount and efficiency of fishing effort (Crutchfield, 1979). Overexploitation of many stocks and widespread overcapitalization of the industry have become increasingly apparent in the north-western and northeastern Atlantic, central eastern Atlantic, and Pacific Oceans.

These realities, and the fact that nearly two-thirds of currently exploited fishing grounds are within two hundred miles of the coasts of developing countries, have recently resulted in the adoption, by many nations participating in the United Nations Law of the Seas conferences, of the Extended Economic Zones (EEZ) principle. This principle acknowledges the sovereign rights of coastal states over 200-mile fishing zones, although these rights are implicitly diminished by the requirement that a coastal state, where it "does not have the capacity to harvest the entire allowable catch, give others access to the surplus," (Copes, 1979). However, the coastal state itself defines the total allowable catch and can, therefore, set the amount of foreign effort.

The U.S. Position

The U.S. stance was at odds with the EEZ concept from its inception in 1971, but an abrupt about-face policy in the mid-1970's led to the American acknowledgement of the principle, and its national expression through the Fisheries Conservation and Management Act. The Act (PL 94-265) was first implemented in the spring of 1977; it set a "fishery conservation zone" within two hundred-odd miles of the coast. The "optimum yield" for various key species is estimated yearly by the National Marine Fisheries Service, which then forecasts the quantity likely to be caught by domestic vessels, and makes the remainder available to foreign nations. Once the amount of total foreign allowable catch is known and made public, foreign nations are invited to submit requests for specific species in well-defined areas.

Licensed foreign vessels pay a permit fee on gross registered tons of effort applied to the stocks, a poundage fee (3.5 percent of the U.S. dockside value of fish), and a surcharge going to a fund used to compensate American fishermen whose vessels or equipment are lost or damaged following the activities of foreign fleets. Finally, foreign vessels are assessed the per diem cost of maintaining an American observer on board.

The most notable economic aspect of the Act is that it fails to capture the rent -- increased because total effort is now controlled -- accruing to domestic and foreign fishermen alike. The collection of revenues from domestic fishermen is prohibited, and revenues from foreigners are limited to the costs of carrying out the provisions of the Act with respect to foreign fishing (stock assessment, negotiation, control and transaction costs). The version of the Act introduced by the Senate wanted to "take into account the value of the fishing privilege" to the foreign vessels, but the final law did not reflect this.

In addition to the loss of fishing rent captured and retained by foreigners, the Act fails to establish safeguards against current or potential inefficiencies in the domestic fleet: as Lee Anderson (1975) remarked: "the ability to restrict foreign vessels from fishing in domestic waters will be only a stopgap measure if proper management of national boats is lacking." This sentiment was echoed by J.A. Crutchfield (1979), who pointed out the resulting "gold rush" tendency emerging in New England to supplant redundant foreign capacity with redundant American vessels.

THE MODEL

This model extends the Schaefer approach (see Schaefer, 1959) to situations in which effort is both domestic and foreign. The basic scenario of the model reflects the current situation of many Third World coastal states; a single-species fishery is exploited at or near the open-access level of effort by a relatively small amount of domestic effort and a large number of foreign vessels. The coastal state (or regional group) seeks to maximize the total domestic benefits through rent maximization and taxation of all foreign rents.[1] Cases in which the domestic price for fish is equal to or lower than the foreign price will be investigated. In both cases a tax on effort and a tax on catch will be examined. Since the optimal policy will require a reduction in effort from the open-access level, the second part of the analysis will be dynamic in nature and will explore two possible paths leading to the optimal steady-state levels of stock and effort.

We make several standard simplifying assumptions. The logistic growth function for a single species stock is assumed, i.e.:

$$X(t) = \frac{X^{\infty}}{1 + C_1 e^{-\alpha t}}$$

where $X(t)$ is the stock level at time t, X^{∞} is the population equilibrium in the absence of fishing, α is the natural rate of increase, which remains constant over time, and C_1 is a constant equal to $\frac{X^{\infty} - X_o}{X_o}$, with X_o being the initial stock level. Alternatively, the logistic equation may be written,

$$\dot{X} = \frac{dX(t)}{dt} = \alpha X(t) \left[1 - \frac{X(t)}{X^{\infty}}\right].$$

Effort is defined homogeneously with $E(t)$ being the units of fishing effort applied at time t. This implies that the marginal cost of effort is constant, and equal for domestic and foreign fishermen, while total cost is units of effort multiplied by marginal cost, i.e., $TC(t) = aE(t)$, where $TC(t)$ is total cost at time t, and a is marginal cost which remains constant over time. Total catch accrues proportionally to domestic and foreign fishermen according to their respective shares of total effort. The harvest function is $Y(t) = \gamma X(t)E(t)$ where $Y(t)$ is yield at time t, and γ is the catchability coefficient. Recalling that in a steady-state equilibrium,

$$\alpha X(t) \left(1 - \frac{X(t)}{X^{\infty}}\right) - \gamma X(t)E(t) = 0$$

---

[1]If the coastal state's objective is to maximize foreign tax revenue and not total rent, then with a fixed level of domestic effort, optimal foreign effort, and foreign rent will increase; total rent, rent per boat and fish stocks will decrease. The reason behind this result is that the marginal boat receives a percentage of total rent and not the marginal increase in rent.

substituting $Y(t)/\gamma E(t)$ for $X(t)$ and simplifying provides:

$$Y(t) = \gamma X^{\infty} E(t) - \frac{X^{\infty}}{\alpha} \gamma^2 [E(t)]^2$$

which may be rewritten:

$$Y(t) = gE(t) - h[E(t)]^2$$

where $g = \gamma X^{\infty}$, $h = X^{\infty} \gamma^2 / \alpha$. To concretize the exposition we use a numerical example throughout this paper. Here X^{∞} = 150,000 tons; α= .5; a = 9.375; γ = .00025; g = 37.5; h = 01875. These parameters imply that the maximum sustainable yield is 18,750 tons when 1,000 units of effort are applied to 75,000 tons of fish stock.

By assumption the fishery initially operates at the open-access level of effort, thus any movement towards rent maximization requires a reduction in the level of effort. With growth and yield equations as specified, equal prices of fish and constant marginal cost of effort, the open-access level of effort is exactly twice as much as the rent-maximizing level of effort.[2] Domestic fishing effort is assumed to be much smaller than the rent-maximizing level of effort and fixed at level $\bar{D}$ in the short run. With domestic effort fixed and total effort being decreased by fifty percent, the reduction in foreign effort will be greater than fifty percent. This large reduction in foreign effort will induce competition among foreigners for the fewer remaining fishing rights. Since there is no rent in the fishery at the open-access level of effort and the state intends to tax all foreign rent, foreigners are confronted with the choice of leaving the fishery or remaining in the fishery with the same net return as in the original open-access situation. In the numerical example, the domestic price for one ton of fish is one monetary unit. This implies that the open-access level of effort is 1,500 units. $\bar{D}$ is fixed at 250 units of effort, which implies that the initial foreign effort is 1,250 units (see Figure 1).

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[2]This is immediate from the following. To maximize rents with respect to effort:

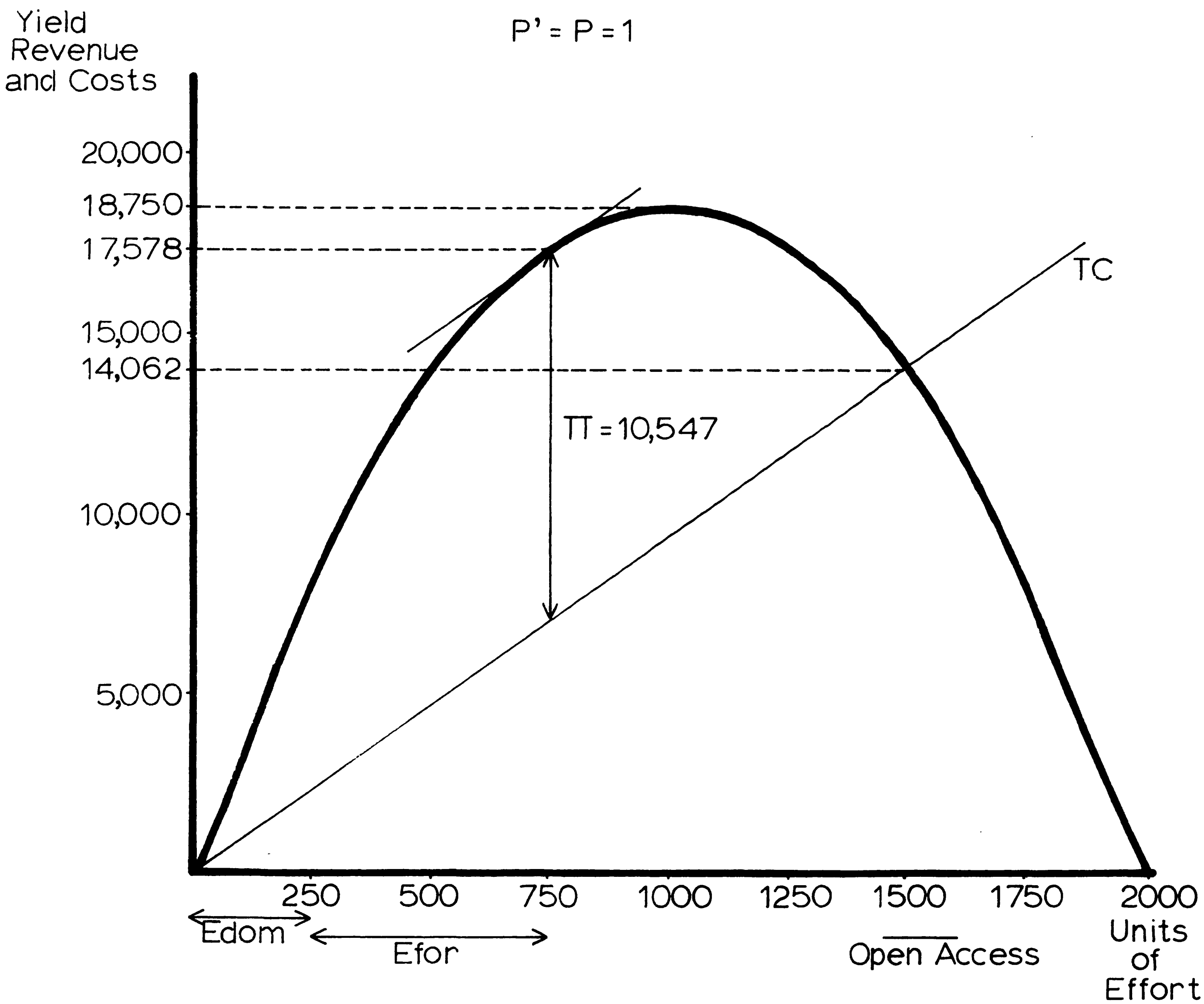
$$\pi = P \; [gE - hE^2] - aE,$$

$$\frac{d\pi}{dE} = P \; [g - 2hE^*] - a = 0,$$

which implies $E^* = (Pg - a)/2Ph$. At the open-access level of effort rents equal zero, i.e., $0 = P \;\; gE_o - (E_o)^2 \;\; - aE_o$, which implies $E_o = (Pg - a)/Ph$. Clearly, $E^* = \frac{1}{2} E_o$.

FIGURE 1

P' = P = 1


Yield
Revenue
and Costs
20,000
18,750
17,578
15,000
14,062
10,000
5,000
TC
π = 10,547
250
500
750
1000
1250
1500
1750
2000
Edom
Efor
Open Access
Units
of
Effort

Case 1: (P = P' = 1)

We first consider the case where both domestic (P) and foreign (P') prices for fish are equal. Let π be the net rent from the fishery. The coastal state's objective is to maximize π with respect to the level of foreign fishing effort. Since steady-state analysis is static in nature, time subscripts are suppressed and,

$$\pi = P[gE - hE^2] - aE.$$

Choosing the price of a ton of fish as the numéraire and separating the domestic and foreign effort implies,

$$\pi = g(\bar{D} + F) - h(\bar{D} + F)^2 - a(\bar{D} + F).$$

The first-order condition for rent maximization is:

$$\frac{d\pi}{dF^*} = g - 2hF^* - 2h\bar{D} - a = 0,$$

or

$$F^* = \frac{g-a}{2h} - \bar{D}$$

where F^* is the rent-maximizing level of foreign effort. (Second-order conditions for rent maximization are satisfied by the convexity of π in F.) In the example $F^* = 500$, annual yield is 17,578 tons and total rent is 10,547 monetary units. Both yield and rent are divided proportionally to effort, i.e., 1/3 to domestic effort and 2/3 to foreign effort.

a. Tax on Foreign Effort. -- With $\bar{D}$ fixed, whether domestic rents are taxed by the state or remain in possession of domestic fishermen does not affect the dynamic efficiency of the fishery. Two types of taxes are discussed: a tax on foreign effort and a tax on foreign catch. To capture the entire foreign rent through an effort tax, the state taxes foreign effort at rate T_e^* such that foreign revenues equal foreign fishing costs plus the tax on foreign fishing effort. That is,

$$\left[\frac{g(\bar{D} + F^*) - h(\bar{D} + F^*)^2}{\bar{D} + F^*}\right] F^* - aF^* - T_e^* F^* = 0$$

Solving for T_e^* provides,

$$T_e^* = g - a - h(\bar{D} + F^*).$$

Substituting for F^* and simplifying implies,

$$T_e^* = \frac{g - a}{2}.$$

In the example $T_e^* = 14.06$.

b. Tax on Foreign Catch. -- The entire foreign rent may also be captured by a tax on foreign catch. The state taxes foreign catch at rate T^*_c such that the foreign revenues equal foreign fishing costs plus the tax on foreign catch, that is,

$$\frac{[g(\bar{D} + F^*) - h(\bar{D} + F^*)^2]}{\bar{D} + F^*} F^*(1 - T^*_c) - aF^* = 0$$

Solving for T^*_c implies,

$$T^*_c = 1 - \frac{a}{g-h(\bar{D} + F^*)} = 1 - \frac{AC}{AR}.^3$$

In the example $T^*_c = .6$. Note that when the price received by domestic and foreign fishermen is the same, the rate of taxation the state would apply to the domestic vessels' catch to capture the entire domestic rent is the same as the rate applied to the foreign vessels' catch.

Case 2: ($P = 1$, $P' > P$)

The state retains the objective of maximizing rent from the fishery, but foreigners now sell their catch in a different market, where the price for fish is higher than the domestic price. The adjusted net rent objective function is:

$$\pi = \frac{P\bar{D}}{E}(gE-hE^2) + \frac{P'F}{E}[gE-hE^2] - aE,$$

where P' is the price that foreigners receive. Setting $P = 1$, separating domestic and foreign effort and cancelling terms, the objective function becomes:

$$\pi = (\bar{D} + P'F)[g - h(\bar{D} + F)] - a(\bar{D} + F).$$

The necessary and sufficient condition for rent maximization is:

$$\frac{d\pi}{dF^{*\prime}} = -h\bar{D} + P'g - P'h\bar{D} - 2F^{*\prime}P'h - a = 0,$$

or

$$F^{*\prime} = \frac{g}{2h} - \frac{\bar{D}}{2P'} - \frac{\bar{D}}{2} - \frac{a}{2P'h},$$

---

[3] That $T^*_c = 1 - \frac{AC}{AR}$ follows directly from the objective of capturing the entire foreign rent, since total revenue equals total cost plus total tax, i.e.,

$$TR = TC + \text{Total Tax},$$

then,

$$AR = AC + \text{Average Tax},$$

$$T^*_c = \frac{\text{Average Tax}}{\text{Average Revenue}} = 1 - \frac{AC}{AR}.$$

where $F^{*'}$ is the rent-maximizing level of foreign effort when foreigners receive a different price. Recalling that for $P = P' = 1$, $F^* = \frac{g-a}{2h} - \bar{D}$ then $F^* < F^{*'}$ when $P'>1$. That is, when foreigners receive a higher price, total rent in the fishery is maximized at a higher level of foreign and thus total effort. (At an infinite foreign price, the optimal level of effort would equal the maximum sustainable yield level!) In the example, if $P' = 2$, then $F^{*'} = 687.5$, annual yield is 18,677 tons, and total rent is 23,522 monetary units. Foreign catch is 13,634 tons or 73 percent of total catch, while foreign rent amounts to 86 percent of total rent (see Figure 2).

a. <u>Tax on Foreign Effort P' > 1</u>. -- To capture the entire foreign rent at the optimal level $F^{*'}$, the state taxes foreign effort at rate $T_e^{*'}$ such that:

$$\frac{P'F^{*'}[g(\bar{D} + F^{*'}) - h(\bar{D} + F^{*'})^2]}{(\bar{D} + F^{*'})} - aF^{*'} - T_e^{*'}F^{*'} = 0.$$

Substituting for $F^{*'}$, solving for $T_e^{*'}$ and simplifying provides:

$$T_e^{*'} = \frac{\frac{g}{P'} - a + h\bar{D}(P' - 1)}{2}.$$

Noting that $T_e^{*'} = \frac{g-a}{2}$ when $P = P' = 1$, $P' > 1$ implies $T_e^{*'} > T_e^*$. In the example with $P' = 2$, $T_e^{*'} = 30.5$ monetary units per unit of effort. If the state also wishes to capture the entire domestic rent, it must use a lower domestic tax rate since $P = 1$. Here the domestic tax rate is 10.5 monetary units per unit of effort.[4]

b. <u>Tax on Foreign Catch</u>. -- To capture the entire foreign rent arising from the $F^{*'}$ level of effort the state can tax catch at rate $T_c^{*'}$ such that:

$$\frac{P'F^{*'} - T_c^{*'}F^{*'}[g(\bar{D} + F^{*'}) + h(\bar{D} + F^{*'})^2]}{\bar{D} + F^{*'}} - aF^{*'} = 0,$$

which implies,

$$T_c^{*'} = 1 - \frac{a}{P'[g-h(\bar{D}+F^{*'})]} \quad 1 - \frac{AC}{AR}.$$

In the example $T_c^{*'} = .765$; that is, 76.5 percent of the value of each fish to foreigners is taxed. The corresponding domestic tax rate is 53 percent of the domestic value of each fish.

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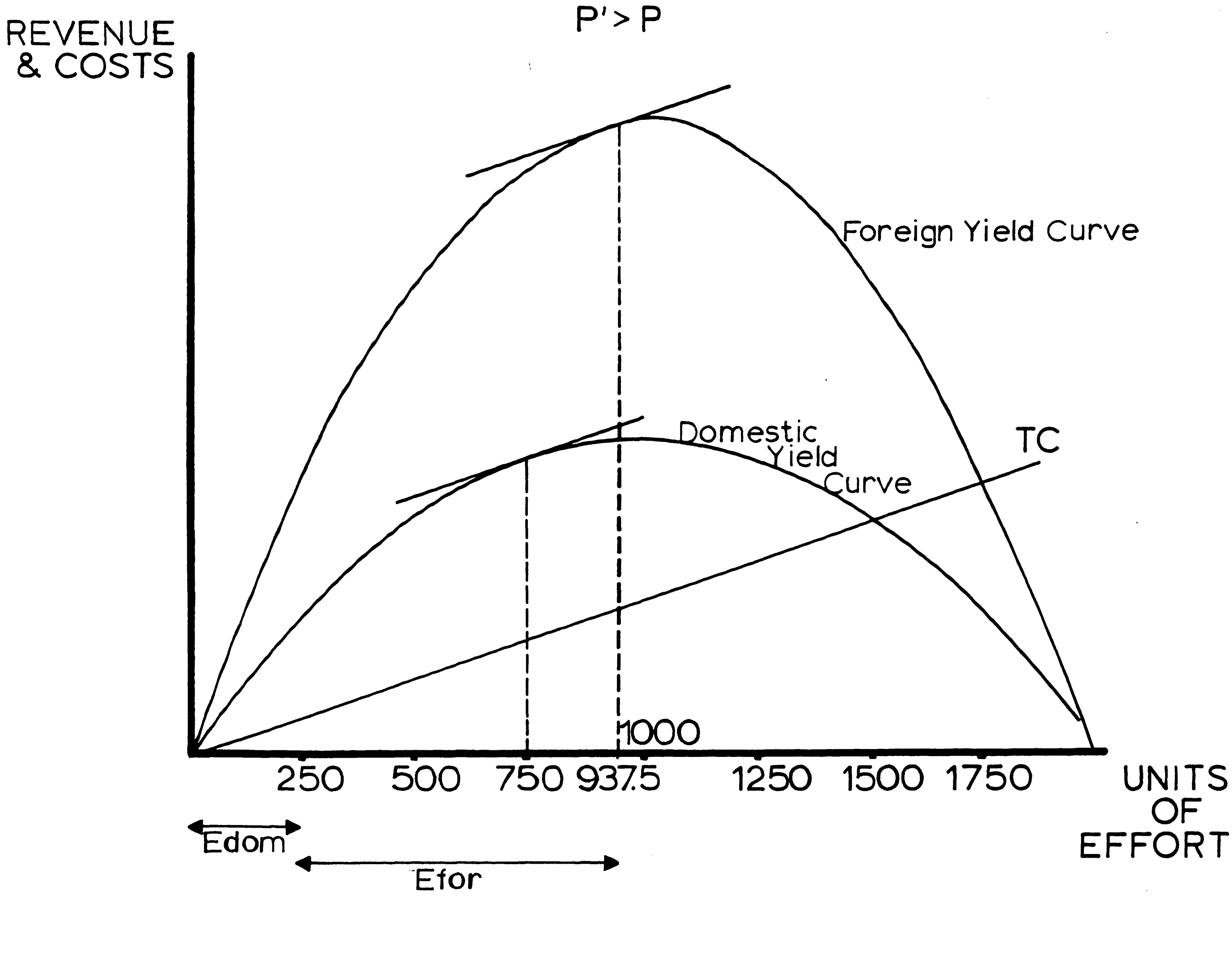
[4]The tax on domestic effort is lower than in the case $P = P' = 1$, because domestic catch and hence domestic rent has fallen due to the increase in total fishing effort.

FIGURE 2


P' > P
REVENUE & COSTS
Foreign Yield Curve
Domestic Yield Curve
TC
1000
250
500
750
937.5
1250
1500
1750
UNITS OF EFFORT
Edom
Efor

DYNAMIC RENT MAXIMIZATION

Given that the fishery has been operating at the open-access level of effort, rent maximization over time requires an initial reduction in fishing effort until the stock reaches the optimal level. The rent-maximizing level of effort is then applied from this point. Since different prices for domestic and foreign catch, or a known changing price, do not alter the character of the analysis, we assume $P = P' = 1$. Assuming that rents are discounted at rate r, the coastal state's dynamic objective function is:

$$\text{Max} \int_0^\infty e^{-rt} [\, Y(t) - aE(t)] \; dt$$

or

$$\text{Max} \int_0^\infty [\gamma X(t)E(t) - aE(t)] dt,$$

which is to be maximized with respect to effort. The equation of motion is:

$$\frac{dX(t)}{dt} = \alpha X(t) \;\; (1 - \frac{X(t)}{X^\infty}) - \gamma X(t)E(t),$$

with initial condition $X(0) = X_o$.

Since the objective function is linear in effort and the initial population stock is less than the optimal population stock, the rent-maximizing policy requires a complete moratorium on fishing until the optimal stock size is reached, and the application of the rent-maximizing level of effort in each period thereafter. That is $E(t) = 0$ until t_1 is such that $X(t_1) = X*$, then $E(t) = E*$ for $t > t_1$. The discounted rent from this complete moratorium policy would be:

$$\int_0^{t_1} 0 \;\, dt + \int_{t_1}^\infty e^{-rt} \;\; E*(t) \;\; [\gamma X(t) - a] \;\, dt.$$

Since the fishery is in a steady-state after t_1, with $E(t) = E*$ and $X(t) = X*$, this implies net benefits are:

$$E* [\gamma X* - a] \int_{t_1}^\infty e^{-rt} dt.$$

After t_1, both domestic and foreign effort must be controlled by taxation or licensing lest the positive rent be dissipated through the addition of further domestic effort.

In most cases, political constraints prohibit a complete year-long moratorium on domestic vessels. The corresponding constrained rent-maximizing policy is one in which only domestic vessels currently in the water will remain in the fishery until the optimal stock size is reached, at which point the rent-maximizing level of effort would be applied in each period thereafter. That is $E(t) = \bar{D}$ until t_2 is such that $X(t_2) = X^*$, then $E(t) = E^*$ for $t > t_2$. The amount of discounted rent from this suboptimal policy would be:

$$\int_0^{t_2} e^{-rt}\ \bar{D}\ [\gamma X(t) - a]\ dt + \int_{t_2}^{\infty} e^{-rt}\ E^* [\gamma\ X(t) - a]\ dt,$$

or

$$\bar{D} \int_0^{t_2} e^{-rt}\ [\gamma X(t) - a]\ dt + E^* [\gamma\ X^* - a] \int_{t_2}^{\infty} e^{-rt}\ dt.^{5}$$

It is possible to compute the cost of rent foregone under the suboptimal policy relative to the complete moratorium. Clearly, $t_1 < t_2$ and after t_2 rents would be equal under both policies. Therefore, adoption of the suboptimal policy implies benefits are foregone only during the period 0 to t_2. The discounted rent from 0 to t_2 under a complete moratorium would be:

$$E^* [\gamma\ X^* - a] \int_{t_1}^{t_2} e^{-rt}\ dt.$$

The discounted rent under the suboptimal policy from 0 to t_2 would be:

$$\bar{D} \int_0^{t_2} e^{-rt} [\gamma\ X(t) - a]\ dt.$$

The discounted rent foregone by adopting the suboptimal policy equals the difference. Explicit analytical evaluation of rent foregone is impossible because the integral solution to:

$$\bar{D} \int_0^{t_2} e^{-rt} [\ \gamma\ X(t) - a\ ]\ dt,$$

---

[5]Some details may be noted. If the coastal state's objectives include the capture of domestic rent during the limited moratorium, then regardless of whether catch or effort is taxed, the tax rate will need to change continuously as rent changes. If $P' > P$, allowing domestic boats to remain in the fishery while foreign boats are excluded, it reduces total and per boat rent.

is not known when X(t) is replaced by a function of parameters and time. Note that X(t) may be determined by separating and integrating the equation of motion. Recall that:

$$\frac{dX(t)}{dt} = \alpha X(t) \left[1 - \frac{X(t)}{X^{\infty}}\right] - \gamma X(t) \bar{D},$$

which implies,

$$X(t) = \frac{X^{\infty} (\alpha - \gamma \bar{D})}{\alpha + C_2 e^{-(\alpha - \gamma \bar{D})t}} ,$$

where

$$C_2 = \frac{\alpha X^{\infty} - \alpha X_o - \gamma X^{\infty} \bar{D}}{X_o} .$$

Substituting for X(t) in the rent expression provides,

$$\bar{D} \int_0^{t_2} e^{-rt} \left[\frac{\gamma X^{\infty} (\alpha - \gamma \bar{D})}{\alpha + C_1 e^{-(a - \gamma \bar{D})t}} - a\right] dt.$$

Since α, γ, $\bar{D}$, X^{∞}, C_2 and a are constants, this may be rewritten:

$$\bar{D} \int_0^{t_2} \frac{e^{-rt} C_3}{1 + C_4 e^{-C5t}} dt + \bar{D} \int_0^{t_2} e^{-rt} a\, dt,$$

where C_3, C_4, C_5 are appropriately defined constants. The solution to the first integral is not known.

However, X_o, X^*, t_1 and t_2 may be explicitly determined, and rent under the suboptimal policy may be approximated, so that the approximate rent from the suboptimal policy may be compared with rent from the optimal policy. X_o and X^* are found by solving the steady-state equation:

$$\alpha X \left(1 - \frac{X}{X^{\infty}}\right) - \gamma X E = 0,$$

for the open-access and rent-maximizing levels of effort respectively. To find t_1 and t_2, it is necessary to solve the equations:

$$X^* = \frac{X^{\infty}}{1 + C_1 e^{-\alpha t_1}}$$

and,

$$X^* = \frac{X^{\infty} (\alpha - \gamma \bar{D})}{\alpha + C_2 e^{-(\alpha - \gamma \bar{D})t_2}}$$

respectively for t_1 and t_2.
Therefore,

$$t_1 = \ln \left[\left(\frac{X^*}{X^{\infty} - X^*}\right) C_1\right] / \alpha$$

and,

$$t_2 = \ln \left[\left(\frac{X^*}{\alpha X^{\infty} - \alpha X^* - \alpha X^{\infty} \bar{D}}\right) C_2\right] / (\alpha - \gamma \bar{D}).$$

For the numerical example, $X(t) = 65{,}625/(.5 + 1.25\ e^{-.4375t})$, $X_0 = 37{,}500$, $X^* = 93{,}750$, $t_1 = 3.22$ and $t_2 = 4.19$. The undiscounted rent from a complete moratorium during the period 0 to 4.19 is 10,231 monetary units. The undiscounted rent from the suboptimal policy during the same period is 2,201 monetary units. The rent differential between the two policies is 8,030 monetary units. In this particular example, the suboptimal policy produces only 21.5 percent of the rent that the rent-maximizing policy does. As is apparent from Table 1, if discounting is introduced, the gap in percentage terms narrows. This is due to the fact that no rent is generated from the rent-maximizing policy until t_1, while the suboptimal policy produces rent throughout the entire period. A reduction in the growth rate α has the same effect as an increase in discounting.

SUMMARY AND CONCLUSIONS

Rent-maximizing levels of effort and rent-capturing taxes have been incorporated into the classical Schaefer model with simultaneous domestic and foreign effort. Different foreign and domestic prices, and a level of domestic effort below the optimal have been considered. The derivation of taxes on foreign effort or catch, given equal domestic and foreign prices, is quite straightforward. On the other hand, when foreigners receive a higher price for their catch than do domestic vessels, social rent maximization will be consistent with a higher level of foreign, and thus total, effort. This will generate greater total rent for the state, although private domestic rents will fall.

TABLE 1

COMPARISON OF DISCOUNTED RENTS
UNDER OPTIMAL AND SUBOPTIMAL POLICIES

Discount Rate	Complete Moratorium	Suboptimal Policy	Suboptimal Policy as Fraction of Complete Moratorium (%)
.03	9057	2050	22.6
.10	6713	1738	28.0
.20	4191	1338	31.9
.30	2456	992	40.4

Furthermore, if the state can capture the rent foreigners receive by selling their catch for a price higher than its domestic value, there is no economic reason to substitute a domestic vessel for a foreign one. Conversely, if domestic units can gain access to the more lucrative foreign markets and be taxed by the state, foreign units may be replaced by domestic boats with no loss in total rent to the state. (Actually, the state might be better off to the extent that less surveillance would be required.)

Perhaps the most practical approach on the part of a developing nation or regional group would be to estimate the maximum potential rent each domestic fishing unit could realize at domestic prices, and establish it as the minimum amount of rent to be captured from each foreign vessel. This minimum amount, plus estimated regulation costs, could be used as the starting point in yearly auctions where foreign nations would bid for fishing rights.

Upon departure from an open-access situation, the optimal dynamic strategy requires a complete moratorium until the fish stock reaches the static rent-maximizing level. Wth a potentially high social cost in terms of rent foregone, the adoption of a suboptimal policy in which domestic vessels remain in the fishery may be to the private advantage of the nation's fishermen. Indeed, they would be in favor of a suboptimal policy if these rents were untaxed, and indifferent between open-access and suboptimal policies if rents were taxed away. The social costs of choosing the suboptimal policy over the complete moratorium decrease as the discount rate grows.

Several issues warrant further inquiry. For example, the state's objectives may include increasing the size of the domestic fleet over time. Since the cost of new vessels and equipment could be paid for by the positive rents from the fishery, a number of optimal investment policies exist under different rates of interest. In addition, given uncertainty in catch, there exists a minimum practical level of foreign effort below which regulation costs outweigh any expected rent captured. Finally, the effect of uncertainties as to the size of fish stocks, respective catch, fishing costs, and dockside value could be explored.

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