OPTIMUM ECONOMIC YIELD OF AN INTERNATIONALLY UTILIZED COMMON PROPERTY RESOURCE[1]

LEE G. ANDERSON[2]

ABSTRACT

The exploitation of a common property resource, specifically a fishery, by nationals of two countries is discussed using a simple general equilibrium analysis. The interdependence of their production possibility curves is used to describe the open-access equilibrium yield, local maximum economic yields, and a true international maximum economic yield. Finally a complete description of the conditions necessary for this international maximum economic yield and why they are different from those in a national fishery is presented.

The purpose of this paper is to analyse, using a simple general equilibrium model, the problem of the allocation of resources where common property or open access exists for some of them. The common property or open-access resource will be a fish stock. The economics of fisheries has been quite extensively developed. See for example Gordon (1954), Scott (1955), Crutchfield and Zellner (1962), Turvey (1964), Crutchfield (1965), Christy and Scott (1965), Smith (1969), Copes (1970), Scott and Southey (1970), Gould (1972), Southey (1972), and Anderson (1973). The present paper follows Scott and Southey and uses a production possibility (PP) curve model which takes into direct account all the resources of the economy and not just the fishery. This change in focus is especially useful for analysing economic aspects of international use of common property resources, a problem that has long been recognized but which has received very little treatment to date. The following quote from Christy and Scott (1965:223) summarizes the problem fairly well:

> "Two countries contemplating the same fishery may rightly make different choices about the intensity and combination of fishing activities .... These different valuations are ultimately the result of the obstacles to the movement of factors from one economy to another. More directly, they result from differences in population, national income, and tastes. It is a commonplace of the theory of comparative costs that the same industry may use a different technique in each country, depending on the structure of wages and prices in each place. But it has never, to our knowledge, been pointed out that the ocean is the main locale where these structures clash.... Of course, it is possible to exaggerate these discrepancies. Forces outside the fisheries tend to bring the national wage and price structure into line, through the movement of goods and the sale of services. And within the fishery itself the increasing international trade in this equipment, all tend to press toward a uniform set of labor-capital-fish price-ratios."

The model presented will allow a more formal analysis of these and other problems.

The first section of the paper describes a one country model of the economics of fisheries from a general equilibrium point of view. Results identical to the earlier works are derived as a starting point for discussion. The second section expands the model to consider two nations both having access to the same fish stock and describes the conditions necessary for an international open-access equilibrium yield, for local maximum economic yields (MEY), and for a true international MEY. The third section describes the conditions for an international MEY in more detail and shows the ways in which the countries can go about achieving them. Throughout the analysis is static.

I

Consider a country with a specified amount of resources, a given technology, and exclusive use (either through default or international law) of a fish stock. Using its resources, it can either produce manufactured goods (M) or fishing effort (E) which can be applied to the fish stock to catch fish. Let the implicit function for the PP curve between M and E be:

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[2]Present address: College of Marine Studies, University of Delaware, Newark, DE 19711.

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$$G(E, M) = 0. \tag{1}$$

Assume that it is quasi-concave so that there will be a concave transformation curve between E and M. Let the sustained yield curve of the fish stock (i.e. the production function) be expressed as:[3]

$$F(E) = aE - bE^2. \tag{2}$$

Using this equation assumes that the fish stock will always be in a biologic equilibrium. F will increase until E is equal to $\frac{a}{2b}$ and will thereafter decrease. F will be zero when $E = 0$ and when $E = \frac{a}{b}$. As long as the maximum amount of E possible is greater than $\frac{a}{2b}$ but less than $\frac{a}{b}$, then the PP curve for M and F will be similar to the solid one in Figure 1. (Ignore for the moment the dotted one.) The slope of the curve is:

$$\frac{dF}{dM} = \frac{dF}{dE}\frac{dE}{dM} = -(a - 2bE)\frac{G_2}{G_1} \tag{3}$$

where G_1 is the derivative of G with respect to its first argument, etc. Fish output will be at a maximum when E equals $\frac{a}{2b}$, not when all of the resources are used in the production of E. As long as the marginal productivity of E in fishing is negative, the PP curve will have a positive slope. Switching resources out of effort and into manufacturing will actually increase both F and M. Where E's marginal productivity in F is positive, the PP curve will have its normal negative slope. Because both $\frac{G_2}{G_1}$ and $(a - 2bE)$ increase as M increases (i.e. as E decreases), the curve will be concave to the origin. Also assume that there is a linearly homogeneous social utility function of the form

$$U = U(F, M). \tag{4}$$

As pointed out in the literature cited above (see especially Turvey 1964 and Scott and Southey 1970), as long as no one regulates entry into the fishing industry, profit maximizing individuals will continue to produce or buy E as long as the value of the average catch per unit of E is greater than the price of effort. The effects of this are as follows. If E and M are produced in pure competition, then $-\frac{P_M}{P_E} = \frac{dE}{dM}$. Equilibrium will occur in the open-access fishery when $P_F\frac{F}{E}$ equals P_E; that is when the average return to effort equals its cost. [Smith (1969) has shown that under certain circumstances, the fishery will not reach an equilibrium. For the moment let us ignore this possibility although its effects will be discussed briefly below.] It can be shown therefore that with an open-access fishery and pure competition in the production of E and M, producers will arrange their production such that for any given price ratio the following condition will hold:

$$-\frac{P_M}{P_F} = \frac{F/E}{dM/dE}. \tag{5}$$

Maximum consumer welfare occurs where the slope of the social indifference curve is equal to the price ratio. That is where

$$-\frac{U_2}{U_1} = -\frac{P_M}{P_F}.$$

Therefore a general equilibrium in the production and the consumption sectors of the economy will occur when

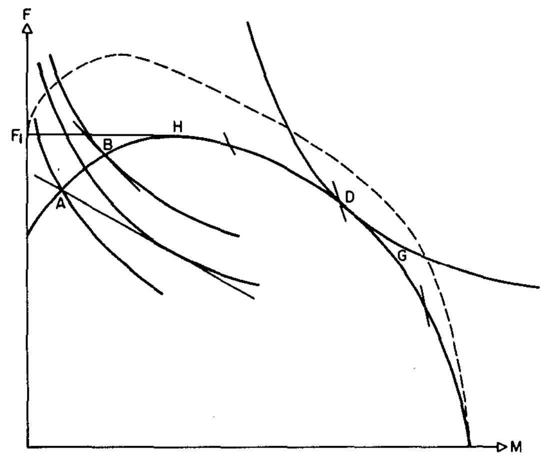

FIGURE 1.—The solid concave curve is the production possibility curve and the set of convex curves are the community indifference curves. Open-access equilibrium will occur at B, maximum sustainable yield at H, and maximum economic yield at D. In the two country model, a decrease in fishing effort in the other country will shift the production possibility curve to the dotted one.

[3]The sustained yield curve is the relationship between the amount of effort expended and the amount of fish that will be captured period after period. The particular expression here follows Schaefer (1957). Although other expressions have been discussed recently (see the papers by Southey and Gould cited above), Expression (1) is descriptive enough to capture the essentials of the argument.

$$-\frac{U_2}{U_1} = -\frac{P_M}{P_F} = \frac{F/E}{dM/dE}. \qquad (6)$$

Conditions for the maximization of social welfare, however, are:

$$-\frac{U_2}{U_1} = -\frac{P_M}{P_F} = \left[\frac{dF/dE}{dM/dE} \equiv \frac{dF}{dM}\right]. \qquad (7)$$

An expression for $\frac{dF}{dM}$ is given in (3) and $(F/E)/(dM/dE)$ can be expressed as:

$$(F/E)/(dM/dE) = -(a - bE)\frac{G_2}{G_1}. \qquad (8)$$

The ratio $\frac{F/E}{dM/dE}$ will increase in absolute size as M increases, and because of the assumption that the maximum E is less than a/b, it will always be negative, even when the slope of the PP curve is positive. It can be seen that when they are both negative, this ratio will be larger in absolute size than the slope of the PP curve at that point; i.e. it will have a steeper slope. The small lines on the PP curve in Figure 1 represent the ratio $\frac{F/E}{dM/dE}$ at that point.

In terms of Figure 1, open-access equilibrium will occur at point B where the slope of the indifference curve as it intersects the PP curve is equal to the ratio of $\frac{F/E}{dM/dE}$ at that point.[4] The social optimum is at point D where the indifference curve is just tangent to the PP curve. The common property or open-access equilibrium will always be to the left of the optimal point; therefore with open access, too many resources will be allocated to F under the market system. It is even possible that the market equilibrium will occur in the positive sloped segment of the PP curve.

By way of comparing the present analysis with the standard one, point H on Figure 1 is the point of maximum sustained yield for a fishery and point D is the MEY. The latter point has less fish but more manufactured goods than the former (and may even have less fish than the point where the unregulated fishery will operate). At MEY, however, no fish is produced unless its value is greater than its opportunity cost. Although MEY in the traditional literature refers to a specified amount of fish production, it assumes that the resources not in fishing are used efficiently in the production of other goods. Describing the model in terms of a PP curve makes this explicit.

Through proper regulation, the country can move to MEY. This could involve a ceiling on the amount of fishing effort allowed or the granting of property rights to the fishery to certain individuals. The former has been tried but usually by means of decreasing efficiency rather than by shifting resources to other types of production, and the latter can lead to monopoly or oligopoly unless the property rights are distributed widely or there are other fish stocks that can provide the necessary competition.

If the government only allows α units of effort, where α is less than the open-access amount of effort, and then distributes the rights to this number of units among a large enough group such that there is still pure competition in the market for both effort and fish, these people will be earning a rent per period, R, of $P_F F(\alpha) - P_E \alpha$ where $F(\alpha)$ is the amount of fish caught by α units of effort. Unless reductions in effort have perverse effects on price, average catch, or cost of effort, this rent will be positive. See Anderson (1973:513).

The optimal amount of effort is where the total amount of rent is a maximum (Christy and Scott 1965:8). By using the standard mathematical procedure it can be shown that the first order condition for R to be a maximum is:

$$P_F \frac{dF}{dE} = P_E .$$

Under the above assumptions, the open-access problem of the fishery has been solved in a way that keeps pure competition in the production of M and E. Therefore $-P_M/P_E$ is equal to dE/dM and so maximization of the rent of the fishery will guarantee that

$$-\frac{P_M}{P_F} = \frac{dF/dE}{dM/dE} = \frac{dF}{dM} \qquad (9)$$

This will mean that the conditions for the maximization of social welfare, expressed in (7) above, will hold. Therefore a policy that maximizes the rent from the fishery also maximizes social welfare.

In summary, a country with exclusive rights to an open-access fishery will operate inefficiently as

[4] As Scott and Southey (1970) point out, if there are increasing returns to scale and if the social utility function is not linearly homogeneous, it is possible that there may be multiple equilibria. I have ignored that complication for purposes of this paper.

long as there is no regulation of fishing effort. This will be because as long as the average returns to fishing are greater than the price of effort, private decision makers will continue to demand E. Also since E and F are directly related, there is always a direct relationship between P_E and P_F.

II

Now to turn to the case of more than one country exploiting the same fish stock, analysis of this is made very difficult by a variety of intriguing problems. For instance, technology may be so different in the two countries that it is very hard to find a common measure of fishing effort, tastes may be such that one country prefers small fish while the other prefers large ones and yet the sustained yield curve is dependent on the size of catch, each country may be using other criteria for harvesting the fish; for example, one may look at it as a place to put unemployed labor, or as a source of earning foreign exchange. For purposes of discussion these intricacies will not be considered.

Assume that two countries, country X and country Y, both with specified production capacities ($G^X(E_X, M_X) = 0$ and $G^Y(E_Y, M_Y) = 0$) and linearly homogeneous community welfare functions ($U^X = U^X(F_X, M_X)$ and $U^Y = U^Y(F_Y, M_Y)$, are the exclusive users of a fish stock with the sustainable yield curve (2) above. Since a unit of effort in country X, (E_X), is identical to one in Y, (E_Y), the sustained yield curve can be expressed as:

$$F(E_Y, E_X) = a(E_X + E_Y) - b(E_X + E_Y)^2.$$

As before the total catch from the fishery will reach a maximum when E_X plus E_Y is equal to $\frac{a}{2b}$ and will fall to zero if total effort gets as large as $\frac{a}{b}$.

The catch of one country will be in proportion to its effort in relation to total effort, therefore:

$$F_X(E_X, E_X) = \frac{E_X}{E_X + E_Y}\left[a(E_X + E_Y) - b(E_X + E_Y)^2\right].$$

This can be simplified to:

$$F_X = aE_X - bE_X^{\,2} - bE_XE_Y. \qquad (10)$$

F_X will reach a maximum when E_X equals $\frac{a - bE_Y}{2b}$ and will fall to zero if it gets as large as $\frac{a - bE_Y}{b}$. The equation for F_Y is analogous.

The amount of fish that country X can catch using a specified amount of E_X depends upon how much E_Y country Y is producing and using. Similarly the catch of country Y depends upon the amount of E_X used by country X. Therefore, the shape and position of each country's PP curve for F and M is dependent upon the amount of E the other country uses. Let the two PP curves in Figure 1 be two possible ones for country X. The solid one is for the larger level of E_Y. Note that the lower curve gets further away from the higher one as M_X decreases. This is because $\frac{\partial F_X}{\partial E_Y}$, the vertical displacement of the curve due to a change in effort in country Y, is equal to $-bE_X$. Therefore, the higher the level of E_X, that is the lower the level of M_X, the greater will be the vertical displacement. The maximum amount of F_X will be at a higher amount of M_X (a lower amount of E_X) because F_X is a maximum when E_X is equal to $\frac{a - bE_Y}{2b}$.

Using this two country model let us consider the implications of three types of exploitation: 1) open access in both countries, 2) local MEY in both countries, and 3) a true international MEY.

From the above description, it can be seen that the shape and position of the PP curve for M and F in each country is dependent upon the level of effort used in the other. Therefore the open-access free market equilibrium in each country will depend upon the level of effort used in the other. The mathematical condition for an international open-access equilibrium is the following set of simultaneous equations:

$$\text{Country } X \qquad \frac{U_2^X}{U_1^X} = \frac{F_X/E_X}{dM_X/dE_X} \qquad (11a)$$

$$\text{Country } Y \qquad \frac{U_2^Y}{U_1^Y} = \frac{F_Y/E_Y}{dM_Y/dE_Y}. \qquad (11b)$$

This simply states that the open-access condition for each country (see Equation (6)) must hold in both simultaneously. In terms of Figure 1, each country must be operating at a point such as B.

Note however, that in country X, average catch (F_X/E_X) is a function of both E_X and E_Y. Therefore an equilibrium in country X can be reached only for a given level of E_Y, (i.e. for a given PP curve). Similarly an equilibrium in country Y is possible only for a given level of E_X. Therefore an international equilibrium is possible only at that combination(s) of E_X and E_Y where Equations (11a) and (11b) both hold simultaneously.

If free international trade between these countries is possible, the price ratios in both countries will be equalized, and so at the equilibrium, the marginal rates of substitution $\left(\frac{U_2}{U_1}\right)$ will also be equal. Therefore the following condition will hold:

$$\frac{U_2^X}{U_1^X} = \frac{U_2^Y}{U_1^Y} = \frac{F_X/E_X}{dM_X/dE_X} = \frac{F_Y/E_Y}{dM_Y/dE_Y} \cdot \quad (12)$$

Graphically the international trade case can be interpreted as follows. For a given level of E produced in the other country, each country will produce at that point on the PP curve where the trade price ratio is equal to $\frac{F/E}{dM/dE}$. It will then trade along the price ratio line until welfare is maximized. Consider a country that would operate under autarky at point B in Figure 1. Under our assumptions the location of the PP curve is related to the amount of E being produced in the other country. If trade opens up with a lower $\frac{P_M}{P_F}$, the production point will move to A, but the consumption point will be at C because of imports of M and exports of F. From this it can be concluded that for each level of E produced in the other country, a decrease in $\frac{P_M}{P_F}$, i.e. a relative increase in P_F, will increase the amount of E produced locally.

As a sidelight notice that the decrease in $\frac{P_M}{P_F}$ actually decreased the welfare of the fish exporting country described in Figure 1. Trade allowed for a further misallocation of resources due to an expanding market for fish to such an extent that welfare fell. Of course, if the price line through A intersected the indifference curve through B, then welfare would have been increased in spite of the harmful effects. To be precise it should be noted that in the general equilibrium analysis, the amount of E produced by the other country will fall in most cases which will shift the PP curve out and may cause welfare to increase enough to overcome the initial loss. On the other hand, increases in $\frac{P_M}{P_F}$ brought about by trade will improve the allocation of resources and always increase welfare initially; however, the increase in E in the other country will have the opposite effect on welfare. So whether the country exports or imports fish, changes in the terms of trade may decrease welfare depending upon the direction and magnitudes of the changes caused by these two factors.

Equation (7) above states the condition for the maximization of social welfare (i.e. MEY) in the one country case. With free international trade, if both countries attempt to maximize welfare given the level of effort used in the other country, the condition for an international equilibrium is:

$$\frac{U_2^X}{U_1^X} = \frac{U_2^Y}{U_1^Y} = \frac{\partial F_X/\partial E_X}{dM_X/dE_X} = \frac{\partial F_Y/\partial E_Y}{dM_Y/dE_Y} \cdot \quad (13)$$

The last two terms can be simplified to $\frac{\partial F_X}{\partial M_X}$ and $\frac{\partial F_Y}{\partial M_Y}$ respectively. These will be recognized as the slopes of the PP curves of the two countries. What this condition states is that for a local MEY, the marginal rate of substitution between M and F in each country must equal each other and they must also equal the internal marginal rate of transformation between M and F given the level of effort in the other country. In terms of Figure 1, each country will be operating at a point such as D, where the slope of the social indifference curve is equal to the slope of the existing PP curve. Notice that in equation (13), $\frac{\partial F_X}{\partial E_X}$ and $\frac{\partial F_Y}{\partial E_Y}$ are both partially determined by the level of effort in the other country, so that here again the equilibrium combination of E_X and E_Y must be simultaneously determined.

One main purpose of this paper is to describe the necessary condition for an international MEY. It is important to note at this time that they are different from Equation (13), the conditions of local MEY's given the level of effort in the other country. Since the level of effort in each country affects the PP curve, and hence potential welfare, in both countries, the maximizing conditions must take this into account. With free international trade, these conditions are:[5]

$$-\frac{U_2^X}{U_1^X}=\frac{U_2^Y}{U_1^Y}=\frac{\dfrac{\partial F_X}{\partial E_X}+\dfrac{\partial F_Y}{\partial E_X}}{\dfrac{dM_X}{dE_X}}=\frac{\dfrac{\partial F_Y}{\partial E_Y}+\dfrac{\partial F_X}{\partial E_Y}}{\dfrac{dM_Y}{dE_Y}}. \quad (14)$$

[5]This condition can be derived in the following manner. With international trade, the community welfare functions become

$U^X = U^X\ [F_X(E_X, E_Y) + F_T, M_X + M_T]$ and

$U^Y = U^Y\ [F_Y(E_Y, E_X) - F_T, M_Y - M_T]$

where F_T and M_T are the amounts of F and M respectively that are traded. If we wish to maximize the welfare of country X subject to a specified amount in country Y and to the productive capacities, we get the following Lagrangian function.

$L = U^X + \lambda_1(U^Y - \bar{U}^Y) + \lambda_2 G^X(E_X, M_X) + \lambda_3 G^Y(E_Y, M_Y).$

The first order conditions for a maximum (using the normal notation for derivatives) are:

(a) $\frac{\partial L}{\partial E_X} = U_1^X \frac{\partial F_X}{\partial E_X} + \lambda_1 U_1^Y \frac{\partial F_Y}{\partial E_X} + \lambda_2 G_1^X = 0$

(b) $\frac{\partial L}{\partial M_X} = U_2^X + \lambda_2 G_2^X = 0$

(c) $\frac{\partial L}{\partial E_Y} = U_1^X \frac{\partial F_X}{\partial E_Y} + \lambda_1 U_1^Y \frac{\partial F_Y}{\partial E_Y} + \lambda_3 G_1^Y = 0$

(d) $\frac{\partial L}{\partial M_Y} = \lambda_1 U_2^Y + \lambda_3 G_2^Y = 0$

(e) $\frac{\partial L}{\partial M_T} = U_1^X + \lambda_1 U_1^Y = 0$

(f) $\frac{\partial L}{\partial F_T} = U_2^X + \lambda_1 U_2^Y = 0.$

Note that Conditions (a) and (c) show that a change in the level of effort in one country has a direct effect on the level of welfare on the other. For this reason the Pareto conditions for an international optimum are different than in the standard case. Solving (e) for λ_1 substituting that expression in (a) and then dividing (b) by (a) yields

$$-\frac{U_2^X}{U_1^X}=\frac{\dfrac{\partial F_X}{\partial E_X}+\dfrac{\partial F_Y}{\partial E_X}}{-\dfrac{G_1^X}{G_2^X}}.$$

Similarly substituting the value of λ_1 into (c) and (d) and then dividing (d) by (c) yields

$$-\frac{U_2^X}{U_1^X}=\frac{\dfrac{\partial F_Y}{\partial E_Y}+\dfrac{\partial F_X}{\partial E_Y}}{-\dfrac{G_1^Y}{G_2^Y}}.$$

Since from (e) and (f) it can be shown that $-\frac{U_2^X}{U_1^X} = -\frac{U_2^Y}{U_1^Y}$, and by definition $-\frac{G_1^X}{G_2^X} = \frac{dM_X}{dE_X}$ and $-\frac{G_1^Y}{G_2^Y} = \frac{dM_Y}{dE_Y}$, it can be shown that Condition (12) holds.

Alternatively this condition can be written as:

$$-\frac{U_2^X}{U_1^X}=-\frac{U_2^Y}{U_1^Y}=\overset{(-)}{\frac{\partial F_X}{\partial M_X}}+\overset{(+)}{\frac{\partial F_Y}{\partial M_X}}=\overset{(-)}{\frac{\partial F_Y}{\partial M_Y}}+\overset{(+)}{\frac{\partial F_X}{\partial M_Y}}. \quad (14')$$

Expression (14) is useful for comparisons with the open-access free market international equilibrium conditions in (12) and with the local MEY condition in (13), while Expression (14′) is useful for tying the analysis to the PP curve.

In words these conditions state that the marginal rate of substitution for M and F and a special type of marginal rate of transformation (MRT) in both countries must equal each other. The marginal rate of transformation is special in that it considers the effect on fish production in both countries, of a change in manufacturing in only one. To be more precise a "socially optimal" international policy should guarantee that neither country expand their fishing effort unless the value of the extra yield, regardless of who catches it, is equal to the value of the extra M that must be foregone. That is country X should compare the opportunity value of producing effort with its effect on local catch $(\frac{\partial F_X}{\partial M_X})$ and with its effect on country Y's catch $(\frac{\partial F_Y}{\partial M_X})$. The same restriction must be placed on country Y's fishing industry also.

It is important to stress at this point that these international MEY conditions were derived by maximizing the level of welfare in one country while specifying a certain level in the other. That is, an initial distribution of the fishery is essential before the maximizing conditions for an international MEY can be utilized. This same condition will hold at many combinations of E_X and E_Y depending upon how the wealth of fishery is distributed. This is one of the major differences between a national MEY and an international MEY. The importance of the beginning distribution will be discussed in greater detail in Section III.

It can be shown from the equations for F_X and F_Y that $\frac{\partial F_X}{\partial E_X} + \frac{\partial F_Y}{\partial E_X}$ equals $\frac{\partial F_Y}{\partial E_Y} + \frac{\partial F_X}{\partial E_Y}$ and that F_X/E_X equals F_Y/E_Y. Therefore in both the open-access equilibrium (Condition 12) and at any true international optimum point (Condition 14), dM_X/dE_X must equal dM_Y/dE_Y. That is, the real cost of producing fishing effort will be the same in both countries. The difference is that only in the latter is the proper amount of it produced. The equalizing mechanism in both cases is the trade in fish which is indirect trade in effort.

Figure 2 depicts the international MEY situation in terms of the PP curve of both countries. Expression (14′) says that the absolute value of the slope of the indifference curves in both countries $(-\frac{U_2}{U_1})$ must be less than the absolute value of the slope of their existing PP curves at the point of operation $(\frac{\partial F}{\partial M})$. That is at the equilibrium point, the slope of the indifference curve must be less steep than the slope of the PP curve. Therefore the slope of the price ratio line must also be less steep than the slope of the PP curve. What this means is that both countries must produce less fish than they would under normal free market conditions given the relative cost of producing F and M. The reason for this is that they must take into account the effect of their output levels on the production of fish in the other country. In the diagram the regulated price ratio common to both countries is represented by the two straight lines. Country X, producing at point A and consuming at point B, is importing M_T units of M and exporting F_T units of F. Country Y, producing at point A′ and consuming at point B′, is doing the reverse. Since at the equilibrium, producers in both countries are basing the production decision on the same price ratio, and since $\frac{dM_X}{dE_X} = \frac{dM_Y}{dE_Y}$, there will be no

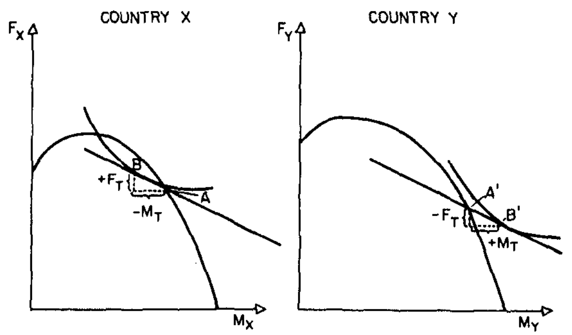

FIGURE 2.—In the two country case, the international maximum economic yield can be represented by the countries producing at A and A′ and consuming at B and B′, the difference being made up by international trade. The exact relationship between the slope of the indifference curves and the production possibility curves is expressed in Equations (14) and (14′).

balance of payments problem; i.e. the value of F traded will equal the value of M traded.

Two technical points regarding this diagram should be pointed out. First, since there are international interdependencies involved, operation at the international MEY requires government regulation. Some form of taxes or other means of control will be necessary in each country to keep producers operating where the price ratio to consumers, as represented by the slope of the indifference curve, is different than the ratio of marginal costs of production, as represented by the slope of the PP curve. Second, it may seem strange that country X, the importer of fish, is consuming at a point inside its existing PP curve. (If the indifference curve for country Y through point B′ intersects the PP curve, that country will also be operating at a point where its welfare is not as large as it might be given its existing PP curve.) Would it not be to its advantage to stop trading and expand its own fishing by moving up its PP curve? In answering this question it must be remembered that the only reason country X's PP curve is as high as it is, is that country Y has reduced its level of effort. Only if country Y were foolish enough to keep its level of effort the same regardless of country X's behavior would the latter benefit from an increase in effort. It would gain welfare while country Y would lose. This discussion points out, however, that proper management of international fisheries will be difficult to enforce because one or both of the countries involved will be motivated to increase effort from the optimal point.

So far three distinguishable points on each PP curve can be identified: the open-access equilibrium point (where the slope of the indifference curve, or the international price line, as it intersects the PP curve equals $\frac{F/E}{dM/dE}$, i.e. point B in Figure 1); the local MEY optima given the level of effort in the other country (where the slope of the indifference curve or the international price line is equal to $\frac{\partial F}{\partial M}$, i.e. point D in Figure 1); and the point where the country contributes to an international MEY given the level of E produced abroad, i.e. at point A or A′ in Figure 2. With regard to the latter, only if both countries are operating in this fashion, is it a true international MEY, where the value of the net increase in fish production by the marginal unit of effort, regardless of its origin, is just equal to the value of the resultant decrease in the production of M.

As a sidelight it is interesting to note that if one country unilaterally adopts a local optimum regulation policy given the level of effort in the other country, at the new equilibrium it will be using less effort and in most cases the other country will react to this by increasing their level of effort. Therefore, while the decrease in effort will increase its level of welfare (it will move from point B to point D in Figure 1), the increase in effort by the other country will shift the PP curve toward the origin, and this will reduce the gains. It is even possible that the shift of the PP curve could be large enough that at the new equilibrium the country actually loses welfare.

This has interesting implications for cases where international cooperation in fisheries management does not exist. National regulation policies must be derived taking into account the reaction of other countries to specific actions. Each country will have to know how the other will react to a change in its level of effort. Taking this into account, it should only reduce its own effort (i.e. transfer resources from producing effort into the production of M) as long as the resultant increase in welfare is greater than the decline due to any possible increase in foreign fishing.[6] If these reactions are not known, the determination of the proper regulation program will require some sort of game theory approach.

In conclusion it should be pointed out that simply because it is possible to list the conditions that are necessary for a certain type of equilibrium to exist does not mean that it will in fact exist. As Smith (1969) has pointed out, a fishery will reach a bionomic equilibrium only if certain relationships exist between the growth rate of the fish stock and the rate at which effort enters and leaves the fishery (either because of market forces or regulatory decree). As pointed out earlier, however, the present analysis is static and will ignore these complications.

III

It will prove useful to view the problem from a different angle. There are two countries each with its own productive capacity and preference function, and between them they share an open-access fishery. Given this information, it is possible to construct a welfare possibility curve for the two countries (Figure 3). Any point on the curve is the maximum amount of welfare that can be obtained for one country at the level of welfare specified for the other country given the productive capacities of both countries and the sustained yield curve of the fishery. At any point on the curve, Condition (14) holds. Therefore, at each point there is an international MEY from the fishery since in all cases the value of the last fish caught will be worth its opportunity cost. As is well known, there is no way of choosing one point on the curve from another.

To digress a moment, if there were no open-access resources or other market imperfections, the two countries through market-directed production and trade will end up at a point on that possibility curve. If they each operated independently, they could obtain a certain amount of welfare, say the amounts represented by point A. Under free market conditions, each would be motivated to change its output combination and then trade such that both would be better off at a point such as B. Point B is not inherently superior to any other point on the curve. It is merely the point where given the productive capacities and the preferences of the two countries, they will operate under the conditions of a free international market. At that point no country can be made better off without making the other one worse off. If for some reason there was a redistribution of productive capacity, the final equilibrium would still be on the curve but at a different point than B.

Now to turn back to the case of the open-access fishery, if neither country exploits the fishery and they do not engage in trade, then operating independently, each would be able to obtain a certain amount of welfare. Again let this point be represented by A in Figure 3. If free trade is introduced and if both countries begin to exploit the fishery taking into account the effect of their effort

[6]In formal mathematical terms the country must maximize welfare subject to its production constraint knowing that the equilibrium level of effort in the other country is a function of its own effort. The proper Lagrangian for country X and its first order conditions are:

$$L_1 = U^X [F_X (E_X, E_Y(E_X)), M_X] + \lambda_1 G^X(E_X, M_X)$$

$$\frac{\partial L_1}{\partial E_X} = U_1^X \left[\frac{\partial F_X}{\partial E_X} + \frac{\partial F_X}{\partial E_Y}\frac{dE_Y}{dE_X}\right] + \lambda_1 G_1^X = 0$$

$$\frac{\partial L_1}{\partial M_X} = U_2^X + \lambda_1 G_2^X = 0.$$

The first order condition with respect to E_X takes into account the total effect on the amount of fish caught by a change in effort. There is the direct change in catch and the indirect effect caused by a change in the level of effort in country Y.

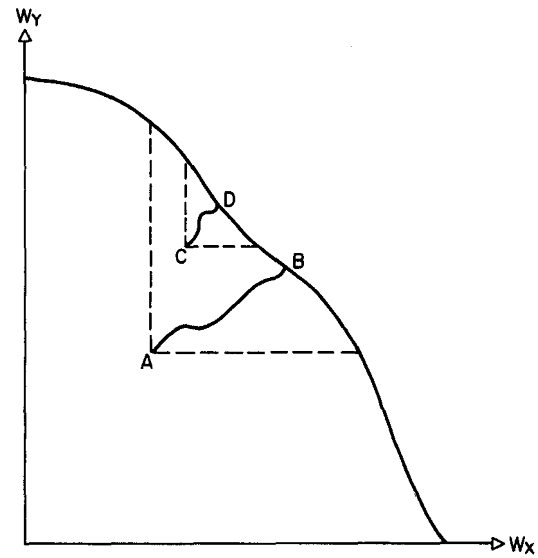

FIGURE 3.—Each point on the curve represents a distribution of the fishery where one country cannot be made better off without hurting the other. B represents the point where it is distributed on the basis of ability to harvest fish. C represents the distribution that is obtained by open-access exploitation. While both countries can benefit from changes from this point, note that in this case a move to the "ability" distribution at B represents a decrease in the welfare of country Y.

on the catch in the other country, a point such as B on the possibility curve will be reached. The wealth from the fishery will have been distributed between the two countries on their ability to produce the effort to harvest it. In fact, if the cost of effort was always less in one country, then at the MEY point, that country would be doing all the fishing and gaining all the wealth from the fish stock. The other country would gain from trade in goods but not from the fishery itself. There is nothing inherently superior about point B, however. There does not appear to be a moral argument that one country deserves the wealth from an international common property resource simply because it has a comparative advantage in the ability to capture it.

Under open-access conditions, the two countries will operate somewhere inside the welfare possibility curve, say at point C. This point is analogous to the solution of Equations (11a) and (11b). It is possible for both countries to increase their welfare by moving to a point such as D. Just how these gains can be obtained is discussed in detail below. But for now notice that in the case depicted here, if the countries are forced to move to point B (i.e. the point where the wealth from the fishery is distributed on the basis of ability to produce effort), country Y will suffer a decrease in welfare. This will not always be the case but will depend upon the position of C relative to that of B.

The point to be made from all this is that distribution is a critical part of determining the makeup on an international MEY. It is important to separate who obtains the wealth from the fishery from who harvests the fish. When the two are linked together, economic efficiency can be obtained only if the fishery is distributed according to ability to harvest. Under these conditions, therefore, one of the countries may suffer a decrease in welfare in the process of obtaining an international MEY. However if distribution and harvesting can be separated, an international MEY can be obtained using any criterion for distribution. Further, one can be obtained whereby both countries will improve their welfare from that at the open-access equilibrium.

The remainder of this paper will discuss a process for reaching an international MEY making explicit the distributional problem and its relationship with Condition (14). Let us consider how two countries that are operating at a point such as C in Figure 3 can move to an international MEY at a point such as D. Such a move would entail up to four mutually inderdependent types of trades between the two countries, including trade in mutual changes in fishing effort (essentially trades that alter, to the mutual advantage of both countries, the property rights to the fishery from those established by the rule of capture in the open-access fishery), trade in fishing effort or rights to fish when one country has the right to fish but the other can produce effort with less cost, and trade in the produced goods F and M. The first of these trades establishes a distribution of the fishery, and the rest insure that Condition (14) will hold for that distribution. These trades are interdependent since any trade can alter demand conditions if the gains are large relative to wealth. Each of these trades will be discussed separately so as to clarify the concepts involved. It should be remembered however, that the theoretical maximum advantage from international cooperation can not be achieved unless the trades are considered simultaneously.

First let us consider the potential for mutual gain from trade in mutual changes in fishing effort. Assume that two countries have reached an international open-access equilibrium with country X producing E_{X1} units of effort and country Y producing E_{Y1} units. (To be completely general this combination of effort can also be thought of as the one that both countries agree to use as an initial bargaining point.) Assume that under these conditions country X is operating at point A in Figure 4a. At that point, which is on social indifference curve I_1, there is a specified amount of E_Y (which determines the shape and position of X's PP curve) and E_X (which determines the position on the curve) being produced. There are other combinations of E_X and E_Y that will cause X to operate on I_1 however. For example, if E_Y remains the same and E_X is reduced (i.e. resources are shifted from the production of effort to manufacturing) such that there is a movement to point B, the level of social welfare will not change.[7] Smaller reductions of E_X that are matched by increases in E_Y will leave welfare unchanged if the increase in E_Y shifts the PP curve down such that the country is still operating on I_1. Similarly, increases in E_X, or reductions by more than is necessary to shift the country to point B, will result in constant welfare if there is a simultaneous reduction in E_Y large enough to shift the PP curve up by the appropriate amount.

This information can be more meaningfully displayed in terms of the property right indifference curves (PRI curves) in Figure 4b. The axis represent allowable levels of E_X and E_Y. These allowable levels are essentially property rights to the annual harvest that the specified amount of E will catch. They are labeled PR_X and PR_Y, but when there is no trade in effort, then E_X equals PR_X and E_Y equals PR_Y. Point A′ represents the international open-access equilibrium point. That is, E_{Y1} is the level of effort in country Y that will cause country X to be operating on the PP curve in Figure 4a, and E_{X1} is the amount of effort in country X that will cause it to operate at point A on that curve. Every other point in the diagram represents a different combination of effort in each country and, in effect, represents a distribution of the fishery. Point A′ is the distribution of the property rights by the rule of capture. Movements to the left represent reductions in the amount of allowable effort for country X, and downward

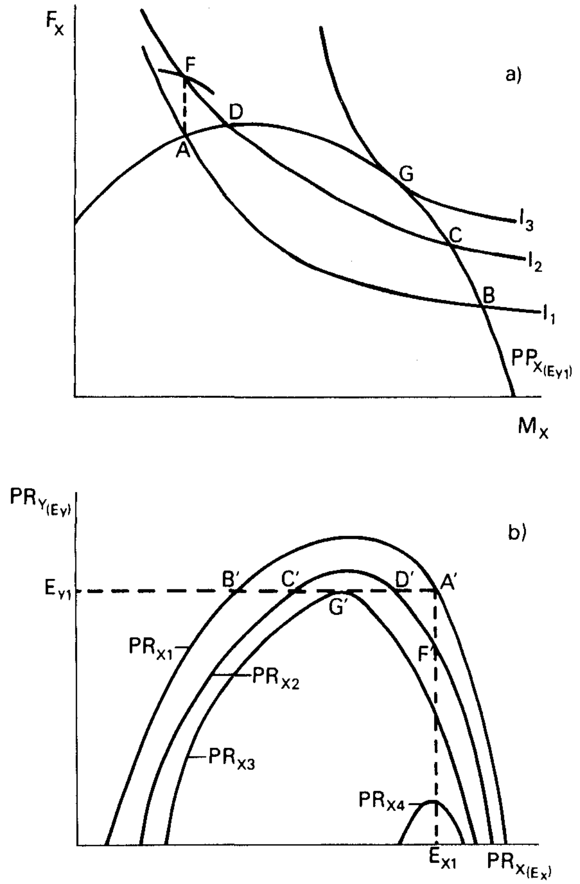

FIGURE 4.—The property right indifference (PRI) curves for each country follow directly from the relationship between their production possibility curves and indifference curves.

movements represent a reduction for country Y. PRI_{X1} is that collection of bundles of PR_X and PR_Y where country X is operating on social indifference curve I_1. Increases in PR_X (movements to the right) will only result in a constant welfare if it is matched by reductions in PR_Y. Small reductions in PR_X with PR_Y remaining unchanged, will normally increase welfare, and so for welfare to remain constant, PR_Y must increase. As reductions in PR_X get larger, however, welfare will remain constant only if there are reductions in both PR_X and PR_Y. Similarly, PRI_{X2} and PRI_{X3} are combinations of PR_X and PR_Y where the level of welfare is the same as along I_2 and I_3, respectively.[8] It

[7]Throughout it is assumed that there is free mobility of resources between fishing and manufacturing. As has been correctly pointed out in the past, this is not always the case. Rather there is a time lag of perhaps as much as a generation involved. This fact should be considered when making practical applications of the model.

[8]The curves will be concave from below. For reductions in allowable levels of effort, the greater the reduction, the greater is the increase in F_X that is necessary to keep welfare constant, and at the same time, the effect of decreases in the allowable

follows then that any distribution of property rights to the fishery represented by a point inside the area delineated by PRI_{X1} will lead to an improvement in welfare in country X over that which is obtained at the international open-access equilibrium. Note that because of the shape of the curve, welfare in country X can actually be increased in some cases where its allowable level of effort decreases while that for the other country goes up. This is possible because at the open-access equilibrium, country X can gain from switching some resources from producing effort to producing the other good and, up to a point, these gains are possible even if country Y increases effort. (Points A, B, C, D, F, and G are analogous to A′, B′, C′, D′, F′, and G′.) The reader should be aware by now of the similarity between these curves and trade indifference curves in international trade theory. Before using these curves in the analysis of the problem at hand, however, a few more points are in order. The short line through I_2 at F is meant to represent the slope of the PP curve if E_X remains constant and E_Y decreases so that country X is operating at F. A decrease in PR_Y will cause the slope of X's PP curve to decrease at every level of M_X.[9] As pictured here it has decreased from a positive to a negative. If it decreases such that it is steeper than the social indifference curve at that point, then the PRI curve will look like PRI_{X4}. That is, the PRI curve will not have a negatively sloped segment to the left of the open-access equilibrium amount of effort for country X. This means that reductions in the allowable level of effort in country X, with the amount in country Y held constant, will always result in a reduction in welfare for country X. Along the same line if country X pursues a local maximizing policy (i.e. it operates at point G in Figure 4a), the international equilibrium will be at point G′ in Figure 4b. This means that under no circumstances will country X be better off if it unilaterally decreases its allowable effort and it will always be worse off if country Y increases its level of effort. This is not the case if the international equilibrium is at point A′.

Figure 5a is similar to Figure 4b except that PRI curves for country Y have been added. PRI_{Y1} has the same meaning for country Y as does PRI_{X1} for country X and is constructed in an identical fashion.

Any distribution of property rights represented by a point inside the area delineated by PRI_{Y1} would result in an increase in the welfare of country Y. It follows then that any combination that is in the area common to both PRI_{X1} and PRI_{Y1} (see hatched area of Figure 5a) will increase the welfare of both countries over that achieved by the open-access "law of capture" distribution of the rights to the fishery. Note again that it is possible for both countries to be better off in some cases where the trade involves a reduction in property rights in one country and yet an increase in the other.

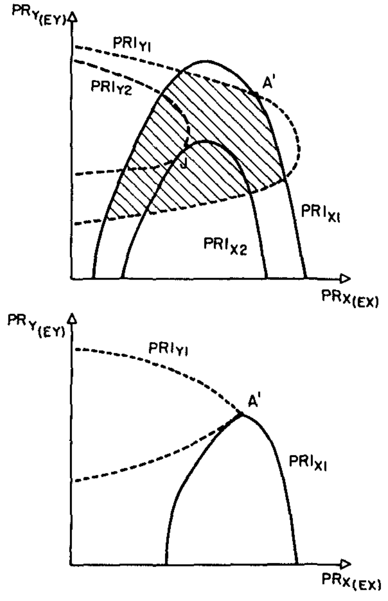

FIGURE 5.—The area common to the initial property right indifference (PRI) curves of both countries represents those distributions of the fishery where both countries will be better off than at the open-access equilibrium. In some special cases, there is no such area (see b).

level of effort in country Y on F_X decreases as E_X increases (i.e. $\frac{\partial F_X}{\partial E_Y} = -bE_X$). Therefore greater reductions in PR_Y will be necessary to compensate for equal reductions in PR_X as the amount of E_X is reduced from the international equilibrium level. For increases in PR_X, the greater the increase the smaller is the marginal increase in fish caught and yet the greater must be the increase in catch in order to keep welfare constant. Therefore greater reductions in PR_Y will be necessary to compensate for equal increases in PR_X as the amount of E_X is increased from the international equilibrium level.

9
$$\frac{\partial F_X}{\partial M_X} = -(a - 2bE_X - bE_Y)\frac{G_2^X}{G_1^X}$$

and so

$$\frac{\partial\left(\frac{dF_X}{dM_X}\right)}{\partial E_Y} = b\,\frac{G_2^X}{G_1^X}.$$

Therefore, as E_Y decreases, the slope will decrease.

It is also possible that in some cases there may be no changes in both E_X and E_Y that will benefit both countries. If both countries adopt a local optimum regulation policy, the PRI's will be of the general shape of those depicted in Figure 5b. In this case, there have to be mutual reductions in order for either country to gain, but as pictured here, there are no mutual reductions that will benefit both countries.

If the governments have the power to control the level of effort in their countries, then it is possible for both of them to increase their welfare by each agreeing to a change in the property right distribution such that the new combination lies within the area described. And further gains are possible if the PRI's for the countries are not tangent at the new point. In other words, given that the equations for the PRI's are of the form $W_{PR} = W_{PR}\,(PR_X, PR_Y)$, further gains are possible unless

$$\frac{\dfrac{\partial W_{PR}^X}{\partial PR_X}}{\dfrac{\partial W_{PR}^X}{\partial PR_Y}} = \frac{\dfrac{\partial W_{PR}^Y}{\partial PR_X}}{\dfrac{\partial W_{PR}^Y}{\partial PR_Y}}, \qquad (15)$$

that is, unless the slopes of the PRI curves are equal. Formally this says that the ratio of the change in welfare in country X due to a change in property rights in country X and to a change in rights in country Y must be equal to the ratio of the change in welfare in country Y due to a change in rights in country X and in country Y. This can be rewritten in terms of the earlier notation as:

$$\frac{U_1^x \dfrac{\partial F_x}{\partial E_x} + U_2^x \dfrac{dM_x}{dE_x}}{U_1^x \dfrac{\partial F_x}{\partial E_y}} = \frac{U_1^y \dfrac{\partial F_y}{\partial E_x}}{U_1^y \dfrac{\partial F_y}{\partial E_y} + U_2^y \dfrac{dM_y}{dE_y}}. \qquad (15')$$

The change in welfare in either country due to a change in its allowable effort is equal to the change in welfare due to a change in F times the change in F due to a change in allowable effort plus the change in welfare due to a change in M times the amount of M that must be given up to produce the extra allowable effort. The change in welfare in the other country is simply the change in welfare due to a change in F times the change in F due to a change in allowable effort in the first country.

Where the final trading position will be and hence what the exact gain to each country is cannot be accurately determined in advance. It depends however upon the international free market equilibrium distribution of the property rights to the fishery which determine the position of the PRI's, the trading ability of the two countries, the extent of the knowledge concerning each other's PRI's, and the number and particular composition of any small trades that lead up the final equilibrium. It would be possible to construct offer curves from the PRI's similar to the ones used in international trade theory, but since trade in mutual changes in property rights will necessitate intergovernmental negotiations and since they will, more than likely, take place on a lump-sum basis, the equilibrium determined by their intersection would be of doubtful significance.

To summarize this discussion let us consider point J in Figure 5a, which is one possible final trading position. Notice that it is not possible to redistribute the property rights from that point without forcing one of the countries to suffer a loss in welfare; that is, there are no further changes in the distribution of the property rights that will be mutually beneficial. This is one of the conditions that must hold for an MEY of an international fishery. It determines the amount of fish that should be caught and the distribution of the rights to catch it. An important point to remember however is that this condition will not guarantee that the fish are caught at the lowest possible cost, and yet this is a very important aspect of MEY.

Let us now consider the potential for mutual gains from trade in actual property rights or in fishing effort. Such trade is not possible unless the rights to fish have been formalized either at the open-access equilibrium or at some other mutually agreed upon point. Again it should be remembered that this is only one type of trade, and the degree to which each country is willing to engage in it depends to some extent upon the makeup of the other trades.

Just because a country has the right to fish does not mean that it should necessarily produce the effort to catch the fish. For instance, if the opportunity cost of producing effort is cheaper in X, then both countries can gain if X expands the production of effort and then sells the increase to Y, who must make a corresponding reduction in its production of effort. If the price of effort for these international sales is between that in each country, both will be able to gain. Country X will gain because it is getting more for the effort that it cost to produce. Country Y will gain because it can buy effort cheaper than it can produce it at home. These mutually beneficial trades can continue until the opportunity cost of producing effort is the same in both countries, i.e. until:

$$\frac{dM_X}{dE_X} = \frac{dM_Y}{dE_Y} \; . \tag{16}$$

The same thing could be accomplished by X purchasing rights to apply effort from Y until the MRT's for E and M are equal. Assume for simplicity that $P_F^Y = P_F^X$. Initially the price for a right to use one unit of effort would have to be somewhat above the rent the right-holder in Y would earn by doing the fishing himself. ($R_Y = P_F^Y \frac{F(\alpha)}{\alpha} - P_E^Y$, where α in this case is the total of the allowable efforts from both countries.) People in X will be able to pay more than that since P_E^X is less than P_E^Y. In trade equilibrium the prices of fish and effort are the same in both countries, and therefore the rents in both countries will be identical and no further gains from trade are possible.

While the above will not change the amount of fish produced, it will make sure that effort is being produced at a minimum cost. The savings can be used to produce more of the manufactured good which can be distributed such that both countries are better off.

Now that two of the possible types of trade have been discussed, it will prove worthwhile to show exactly how they can be interrelated.

Trade in E or in fishing rights may have an effect on the bargaining for the distribution of property rights. To see this, assume that after such bargainings country X is at point D in Figure 4a and at that point $\frac{dM_X}{dE_X}$ is less than $\frac{dM_Y}{dE_Y}$. If it produces q more units of E but sells them to Y who reduces its production of E by the same amount, the PP curve will not change. Initially X will operate somewhere horizontally to the left of point D because it had to give up units of M_X to get the extra units of E. Y will be willing to pay sufficient units of M to X such that it will ultimately operate somewhere horizontally to the right of D and will therefore show an increase in welfare. Therefore at point D′ in Figure 4b, which represents the rights to fish and not the actual amount of E produced in each country, the welfare of X will increase. By similar analysis it can be shown that if trade is possible, Y will always be at a higher level of welfare at D′ also. This means that the PRI's of both X and Y will change shape and position. Therefore more than likely there will be the possibility of further mutually beneficial trades in the distribution of fishing rights.

The final type of trade to consider is trade in the final products M and F. If the relative prices are different in the two countries, mutually beneficial trades can be arranged. These trades can continue to be mutually beneficial until the marginal rate of substitution in both countries is the same, i.e. until:

$$\frac{U_2^X}{U_1^X} = \frac{U_2^Y}{U_1^Y} \, . \tag{17}$$

These trades will be affected by trades in E and also in changes in the allocation of the property rights.

On a practical note it must be admitted that few countries will be willing to let their international trade policy in all goods be dictated by their fishery management program. Therefore it is unrealistic to assume that they will drop all restrictions on international trade on this account.

This means that even after the rights to fish have been distributed, there are four things that can be traded: fish, manufactured goods, effort, and rights to fish. Because the prices of the last two are directly related to those of the first two, the relative demands for M and F will determine the equilibrium set of prices. It is impossible to predict, however, just what the actual trade bundle will be. For instance, nothing in the model allows us to predict whether X will export effort or import fishing rights if it has a comparative advantage in producing effort. The outcome of that, however, will affect its exports or imports of F.

Although the exact makeup of the international MEY position cannot be described, Conditions (15), (16), and (17) must hold simultaneously for it to be in effect. (Condition (15) sets a distribution from which no further mutual gains are possible, and Conditions (16) and (17) guarantee that Condition (14) above will hold for that distribution.) That is all potential mutual gains (where a mutual gain could consist of one country being made better off and the other remaining the same) by (1) altering the distribution of the rights to use effort, (2) trading in actual rights or in effort itself, or (3) trading in final goods, have been achieved. This point (say at point D in Figure 3) is a Pareto point that can be reached by mutually advantageous trades between the two countries given their initial positions which include their productive capacity and the rights to the fishery that they have obtained by the right of capture. At this point there will be an MEY to the fishery. The proper amount of fish will be harvested and at the lowest cost possible. But since there is nothing sacred about these initial positions, point D is not inherently superior to any other point on the curve. If the world order somehow alters their initial positions, for instance, by saying that since Y is a poor country it should be able to expand its effort and X should do the opposite, the same types of trades will still be possible, and they will lead to a point on the curve that is more advantageous to country X than was point D. This point would also be an MEY given the distribution of productive capacity and of the wealth of the fishery. The distribution of the rights to the fishery is very important in determining the MEY of the fishery. Let us consider some of the practical implications of this discussion. First, before an international fishery can be optimally managed, the wealth from it must be distributed. The exact makeup of the distribution is not important, but it is possible, in most cases, to find a distribution whereby both countries are better off than at the initial bargaining point. The rights to the fishery should be transferable if the country owning them is to receive the maximum possible benefit. This way, it can sell the rights or hire effort from other countries to utilize them if it does not have a comparative advantage in producing effort. Therefore, unless the upcoming Law of the Sea Conference can agree to some sort of distribution of the wealth of the fishery and make allowances for possible trades in the makeup of the distribution bundle and also in fishing rights and effort, there is little hope for economically rational management of international fisheries.

The results of this two country, one fishery model can be expanded in a fairly straightforward fashion to a situation where there are many countries that simultaneously exploit several different fisheries. An international open-access equilibrium will occur when, in each country, the average returns from fishing the various stocks are equal to the average cost of providing effort. The distribution of the wealth from the fisheries will depend on the ability of each of the countries to produce the effort that is most efficient for a particular fishery. The more efficient producers will capture a larger share of the fisheries. If perfect international trade in fish products is not possible, then the distribution of the fishery by the "rule of capture" will also depend upon the tastes of the countries. A country that has the potential to harvest a certain type of fish very efficiently but has little desire for the product and cannot use it in international trade will not exploit that stock very extensively.

The usefulness of unilateral regulation in this situation will probably be less than in the two country case. Any reduction in effort will more than likely be met by an increase from one of the other countries. Therefore, while the country will show an increase in the amount of other products it can produce, it is entirely possible that the value of its total production will fall due to the decrease in catch.

Proper international regulation must take into account the effect that effort from one country will have on the yields to other countries exploiting the same stocks. With this consideration in mind, each country can benefit from some program of reallocation of the rights to the fish stocks from that which exists under open access. To achieve the maximum potential benefits, this program should include the possibility of trade in effort, fishing rights, and final products. The existence of many countries will of course make it much more difficult to specify the set of redistributions that would be beneficial to all concerned and even more difficult to get the countries to agree to one combination within that set. A major problem with international regulation is that allocational requirements are just as important as economic efficiency requirements. But given a mutually agreed upon allocation (i.e. a certain allowable level of effort in each country for all fisheries), the efficiency requirements can be met. The problem is to get agreement on a distribution plan with many different countries involved.

SUMMARY AND CONCLUSIONS

In the first section of the paper the general equilibrium model was used to derive the familiar result that in an open-access fishery too many resources will be allocated to the production of fishing effort. Using this model it is possible to explicitly take into account the lost production of other goods. In the second section the general equilibrium model was expanded to include two countries exploiting the same open-access fishery. The amount of effort used in one country will affect the production possibilities in the other by changing the catch per unit of effort. Therefore, there is a direct technical relationship between the two countries. An international open-access equilibrium will exist when the average return to effort is equal to the marginal cost of providing it. (Whether or not such an equilibrium will ever be reached is another question.) The international optimum is where the marginal increase in the value of the fish caught (regardless of the country in which it is landed) is equal to the marginal cost of producing the last unit of effort in both countries. Using this model, two interesting points can be made. First, under open access, what are normally considered to be improvements in the terms of trade, for either the exporter or the importer of fish, can in some circumstances lead to a decrease in welfare. Also attempts at unilateral management can lead to decreases in welfare depending on the way in which the other country's fishing industry reacts. Proper regulation policies should directly take these things into account.

The topic of the third section was the necessary conditions for an MEY of an international fishery. The discussion with its implicit assumptions of governments that are willing and able to negotiate in an open and far ranging manner at zero cost, free trade in all goods, regulation methods that are not at the expense of efficiency, a physically independent fish stock that is only available to two countries, showed if negotiation is possible that an international MEY can be reached. This point will be the MEY of the fishery. (Even if the assumption about the possibility of free trade in final goods is dropped, the analysis of trade concerning the distribution of property rights to the fishery and trade in rights or effort is still valid. Therefore, even if there are different price and cost structures in the two countries, there is a basis for selecting a second best total amount and composition of fishing effort.)

It is also pointed out that there are many points that satisfy the conditions of an international MEY and that the distribution of the rights to the fishery (especially where the wealth from the fishery is large relative to the productive capacities of the countries) and, to a lesser extent, the differences in negotiating ability have an effect on which one will apply at any point in time. (There will not be one point that can be called MEY as in the case of a national fishery.) This is important because fishery negotiations typically work in the reverse. They try to find some optimum total amount of effort that should be applied and then they divide it in some equitable fashion, but it is impossible to choose an optimum amount unless the distribution has already been determined.

With regard to the argument that the underdeveloped countries should be granted preferential treatment in the distribution of the ocean's living resources, the model points out that if this is accepted, it does not mean that they should necessarily do the fishing. Rather, if they do not have a comparative advantage in the production of fishing effort, they would be better off by either selling their rights to the fish or by hiring fishing effort from other countries.

In conclusion this paper has formalized the analysis of the problems of international fisheries management that earlier writers only briefly discussed. To their list of problems of different prices, taste, and cost structures, it adds the effect that the distribution of the wealth of the fishery itself can have on the final outcome. It presents the three conditions for an MEY of an internationally utilized fishery. More generally the conditions guarantee the proper production bundle of all goods and its optimal distribution given the productive capacity of the countries and of the fishery and the distribution of wealth.

Although the discussion has been in terms of a fishery, the analysis could be expanded to other common property resources, such as air and watersheds, deep-sea mineral sources, etc. by taking proper consideration of the various physical characteristics of the resource involved.

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