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# Market Power, Management Regimes, and Strategic Conservation of Fisheries

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**Abstract** *This paper explores the interaction that may exist between national fisheries management regimes through international markets for fisheries products. A two-stage, two-period model is developed in which the fishing industries of a "domestic" country and a "foreign" country harvest identical fisheries products, from separate fish stocks, for the same international market. The domestic country uses a harvest policy to regulate its fishing industry in each period, while the foreign fishing industry is unregulated. Two types of fisheries are considered: schooling fisheries and search fisheries. Given these two types of fisheries, it is shown that the domestic country may choose a conservative harvest policy in the first period in order to induce further degradation, or even destruction, of the foreign fishery in the second period. The results suggest that fisheries trade in the presence of international market power and divergent national fisheries management regimes could have unexpected consequences for world fisheries.*

**Key words** Fisheries management regimes, international trade, strategic behavior.

## Introduction

The United Nations Convention on the Law of the Sea, which entered into force in 1994 but has been accepted as customary international law since 1982, has already had profound effects on global patterns of fisheries production and trade. While it has created well-defined international property rights over most of the world's fisheries, the new Law of the Sea has also transferred international market power in fisheries products from former distant-water fishing countries to coastal countries. It was expected that these effects would provide sufficient incentive for coastal countries to implement efficient fisheries management regimes within their exclusive economic zones (EEZs). However, only a handful of countries have moved toward more efficient management of their fisheries, while the fishing industries in most countries have undergone rapid and unregulated expansion. There has been much concern that international fisheries trade in the presence of inefficient national fisheries management regimes could jeopardize the goal of world fisheries conservation that had been intended with the new Law of the Sea. This paper explores the interac-

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tion that may exist between national fisheries management regimes through international markets for fisheries products.

The paper develops a two-stage, two-period model of a "domestic" country and a "foreign" country whose respective fishing industries harvest identical fisheries products, from separate fish stocks, for the same international market.[1] The domestic and foreign harvests in each period are determined by the zero-profit condition of open access to each fishery. The domestic country uses a harvest policy to regulate its fishing industry in each period, while the foreign fishing industry is unregulated. The domestic country chooses the level of its harvest policy in each period with the objective of maximizing domestic surplus (or domestic economic rent) from fishing. Since there is no harvest policy in the foreign country, the foreign surplus from fishing is zero. Thus, there is an efficient management regime in the domestic fishery and an inefficient management regime in the foreign fishery.[2] The timing of the two-stage game in each period is as follows. In the first stage, the domestic country chooses the level of its harvest policy, and in the second stage, the fishing industries in both countries harvest simultaneously. The model is solved for the subgame perfect equilibrium domestic harvest policy and harvest by domestic and foreign fishing industries in each period.

Naturally, the direct role of the domestic harvest policy is to induce an efficient domestic harvest in each period, but there can also be two indirect or strategic roles: (*i*) to raise domestic surplus from fishing through rent-shifting in the international market in each period; and (*ii*) to induce even more foreign overfishing through the international market in the first period, thereby further raising domestic surplus from fishing in the second period. The first of these strategic roles produces the standard terms of trade argument for government intervention in the presence of international market power at the industry level.[3] However, depending on the type of fishery in each country, the second of these strategic roles can produce rather striking results. In the case of schooling fisheries, the domestic country may choose a conservative harvest policy in the first period in order to induce biological collapse of the foreign fishery in the second period. In the case of search fisheries, the domestic country always chooses a conservative harvest policy in the first period in order to induce further economic degradation, or even economic collapse, of the foreign fishery in the second period.

This paper draws from the literature on trade policy in the presence of international rivalries between industries. Brander and Spencer (1985) and Dixit (1984) examine the strategic role of government intervention in a two-country model of an oligopolistic international market with a fixed number of firms in each country. The optimal domestic harvest policy in the second period of the model developed in this paper is similar to the optimal export policy in Dixit, but the optimal domestic harvest policy in the first period can be quite different under certain circumstances. Barbier and Rauscher (1994), Brander and Djajic (1983), and Brander and Taylor (1997) consider the potential roles of various trade policies that involve resource industries. One common theme in this literature is that trade policies can be used by countries to improve the global efficiency of resource exploitation. This paper develops the opposite theme in the sense that strategic behavior by the domestic coun-

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[1] There is neither a biological interaction nor a physical interaction between the domestic and foreign fisheries; there is only an economic interaction through the international market for their identical fisheries products.

[2] While the foreign management regime is deemed inefficient due to the absence of a foreign harvest policy, this could be the result of a rational choice by the foreign country if management and enforcement costs are prohibitively high.

[3] See Brander (1995) for a comprehensive review of the strategic trade policy literature.

try in the form of a conservative harvest policy can exacerbate the problem of overexploitation of the foreign fishery, or it can even lead to its destruction.

This paper also draws from the literature on strategic interactions between the resource industries of different countries. While Ruseski (1998) examines the role of government intervention in the context of international fisheries, this paper examines the role of government intervention in the context of international markets for fisheries products. Similarly, while Copeland (1990) considers the strategic incentive for countries to underinvest in international fisheries, this paper considers the strategic incentive for countries to overinvest in nationally owned fisheries in order to induce further overexploitation or even destruction of fisheries in other countries. The notion of strategic interaction between countries in current and future markets for resource products has been considered by Salant (1976) and Gilbert (1978) in their studies of the structure of the world oil industry. The notion of fisheries conservation in anticipation of more profitable market conditions in the future has been explored in the nonautonomous dynamic models of Clark and Munro (1975, 1978). Finally, the strategic behavior considered in this paper is similar, in some respects, to intra-industry conduct by firms that raises rivals' costs (Salop and Scheffman 1983).

## Assumptions of the Model

The model developed herein is based on several assumptions. First, the fishing industries in two countries produce from separate fish stocks, and their fisheries products are perfect substitutes in the international market. Second, countries have market power since there is an international duopoly in the first period and the potential for an international monopoly in the second period. Third, the country that uses a harvest policy to regulate its fishing industry can also use this policy to engage in strategic behavior through the international market. In this section, these assumptions are discussed conceptually and through real-world examples in order to better understand the insights of the paper. The discussion here is intended to provide some support for the notion that, under certain conditions, countries with well-managed fisheries may have an incentive to implement conservative harvest policies, if doing so encourages degradation or destruction of fisheries in other countries.

The first assumption—that countries produce identical products from separate fish stocks—reflects the fact that most of the world's traditional fisheries are now under the exclusive jurisdiction of coastal countries. It also reflects the fact that there is often a high degree of substitutability between fisheries products in international markets. For example, Bose and McIlgorm (1996) conclude that there is a high degree of substitutability between bigeye tuna and yellowfin tuna in the Japanese *sashimi* market. Yamamoto (1994) and Owen and Troedson (1994) also indicate that bigeye tuna and albacore tuna have become more popular as substitutes for bluefin tuna in Japan, since its supply has become more scarce due to overexploitation.

While tuna fisheries provide an example of products with a high degree of substitutability in international markets, they do not necessarily provide a good example of separate fish stocks. Another fishery that may provide a better example of both a separate fish stock and a high degree of substitutability in international markets is the New Zealand groundfish fishery. The Food and Agriculture Organization (1997) reports that almost all groundfish production in New Zealand (orange roughy and hoki are the principal species) occurs within its EEZ and that there is a relatively small amount of harvesting activity by other countries in the adjacent high seas. Furthermore, the New Zealand Fishing Industry Board (1996) reports that, while New Zealand accounts for only 3% to 4% of the world's groundfish harvest, almost all of its production is exported to foreign markets. Therefore, the prices of these products depend on the prices of cod, pollock, and other groundfish species caught in the rest of the world.

The second assumption—that countries have market power—is harder to illustrate using a current, real-world example considering the fact that there are substitutes (to a greater or lesser degree) for many fisheries products. However, one example of at least the potential for market power could be the South Pacific skipjack and yellowfin tuna fisheries. Campbell (1996) reports that the small countries of the Pacific Islands Region (PIR) provided around 30% of the world tuna harvest in 1990. Campbell also indicates how, through the access fees paid by distant-water fishing nations for access to their EEZs, there is considerable potential for PIR countries to exercise market power in terms of the world supply of canning tuna.

The third assumption—that a country with a well-managed fishery and market power can engage in strategic behavior—is also hard to illustrate using a current real-world example. Nevertheless, while not an ideal example for the purpose of this paper, such strategic behavior could someday occur in the New Zealand groundfish fishery, and, more specifically, the hoki fishery. Hoki is a species found only in the coastal and high-seas waters around the South Island of New Zealand, the south coast of Australia, and Tasmania. The Food and Agriculture Organization (1997) reports that New Zealand accounted for over 80% of the 248,000 metric ton world hoki harvest in 1994. The Food and Agriculture Organization (1997) also reports that, for so-called "marketing reasons," the New Zealand hoki harvest has been consistently less than the total allowable catch (TAC) in recent years.[4] Even though hoki products compete with other groundfish products in international markets, the industry seems to recognize that a higher TAC leads to lower prices offered by buyers for hoki products.

The strategic behavior analyzed in this paper could occur in the future if most of the world's fisheries continue to be mismanaged, while some coastal countries continue to move toward more efficient management of the fisheries within their EEZs. During a conference on the interaction between fisheries management practices and international trade in fisheries products, it was remarked that recent growth in exports of high-valued fisheries products has been concentrated in the aquaculture sector and well-managed fisheries. It was then noted that, "One could interpret the ... findings to mean that coastal states with well-managed fisheries, such as New Zealand, should encourage ongoing fisheries mismanagement in the rest of the world in order to be left as one of the few remaining stable sources of supply" (Pacific Economic Cooperation Council 1997, p. 7). How might countries with well-managed fisheries encourage ongoing mismanagement of fisheries in the rest of the world? This paper suggests that one possible mechanism for such strategic behavior is through international markets for fisheries products.

## Biological and Economic Characteristics

Two types of fisheries are considered in this paper: schooling and search fisheries. These fisheries can be differentiated by their biological and economic characteristics. In terms of their biological differences, Clark (1990) and Pitcher (1995) describe how certain species of fish often swim in dense schools as a defense mecha-

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[4] For instance, the Food and Agriculture Organization (1997) reports that the New Zealand hoki harvest was only 174,972 metric tons, 79.4% of the TAC, in the 1995–96 fishing season.

nism against natural predation or during spawning activities. In contrast to other species, the schooling tendency of these species often implies a natural mortality rate that increases as the size of the fish stock decreases. This, in turn, leads to a growth function that exhibits *critical depensation*: growth can become negative if the size of the fish stock should ever fall below some critical level. Since, by definition, other species of fish do not have this schooling tendency, the natural mortality rate for these species most often decreases as the size of the fish stock decreases. This leads to a growth function that exhibits *compensation*: growth cannot become negative as the size of the fish stock decreases. The growth function used in this paper can be modified to exhibit either critical depensation or compensation by changing the numerical value of a single parameter.

Building on the models of Mason and Polasky (1994) and Clark (1973), the sizes of the domestic and foreign fish stocks in period $t$ are denoted by $S_t$ and $S_t^*$, respectively, for $t = 1, 2$. The foreign fish stock is linked from one period to the next by the growth function $S_{t+1}^* = f(S_t^* - y_t)$, where $y_t$ denotes the harvest by the foreign fishing industry. Letting $r = S_t^* - y_t$, the growth function $f(r)$ has the following properties: $f(r) > r$ for $\underline{S} < r < \bar{S}$; $f(r) = r$ for $r = \underline{S}, \bar{S}$; $f(r) = 0$ for $r < \underline{S}$; $f' > 0$ and $f'' < 0$ for $\underline{S} \leq r \leq \bar{S}$. The fish stock is assumed to lie between $\underline{S}$ and $\bar{S}$ initially. It is also assumed that the harvest cannot exceed the size of the fish stock such that $S_t^* \geq y_t$ or $r \geq 0$. Similarly, the growth function for the domestic fish stock is $S_{t+1} = f(S_t - x_t)$, where $x_t$ denotes the harvest by the domestic fishing industry, and, therefore, has the same properties as the growth function for the foreign fish stock.[5]

Think of $\bar{S}$ as the natural, unexploited size of the domestic and foreign fish stocks, and $\underline{S}$ as the *critical minimum stock size*. If the remaining stock of fish minus harvest should fall below $\underline{S}$ in any period, then biological collapse of the fishery will occur in the next period. In the case of schooling fisheries, it is assumed that $\underline{S} > 0$ to reflect the potential for biological collapse due to critical depensation in the growth function. In the case of search fisheries, it is assumed, instead, that $\underline{S} = 0$ due to compensation in the growth function. An illustration of the properties of the growth function for the case of schooling fisheries is provided in figure 1. The properties of the growth function for the case of search fisheries are illustrated instead if $\underline{S} = 0$, which would then make this figure the same as figure 1 in Clark (1973).

In terms of their economic differences, Neher (1990) describes how it is relatively more difficult to harvest from a search fishery than from a schooling fishery, because nonschooling species have a tendency to spread out over their fishing grounds. This tendency implies that the density of fish increases as the size of the fish stock increases. This, in turn, implies that the harvest cost function for a search fishery depends on the size of the fish stock—the larger the fish stock, the lower the cost per unit of harvest.[6] For schooling fisheries, however, the cost per unit of harvest need not depend on the size of the fish stock, since the density of fish in individual schools does not depend as much on the size of the fish stock.[7]

The cost function in the domestic fishery is assumed to be $C(x_t) = c(x_t)x_t$ for a

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[5] The growth function used in this paper is just a two-period version of the recursive stock-recruitment relation in Clark (1990) that has been modified to allow for biological collapse of the fishery between one period and the next.

[6] A similar discussion in Clark (1990) emphasizes how differences in “concentration profiles” between species leads to different harvest cost functions. Wilen (1985) provides an alternative formulation of the harvest cost function for a search fishery in which the cost of time spent “searching” and the cost of time spent “fishing” are distinguished.

[7] Paradoxically, Pitcher (1995) and Mackinson, Sumaila, and Pitcher (1997) describe how the cost per unit of harvest for some schooling fisheries could actually decrease as the size of the fish stock decreases. This is because the behavioral response to stock decline often involves a reduction in the range over which schools travel, with no significant reduction in the average school size.

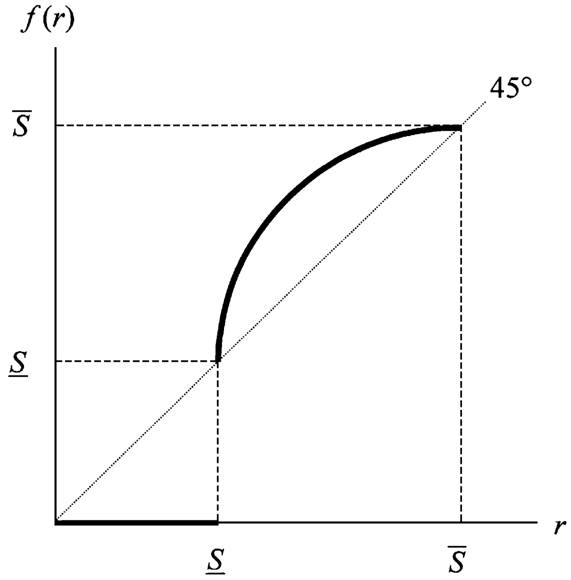


**Figure 1.** The Growth Function for Schooling Fisheries

schooling fishery, such that the cost per unit of harvest is $c(x_t)$, and, following Mason and Polasky (1997), $C(x_t, S_t) = [c(x_t) + d(S_t)]x_t$ for a search fishery, such that the cost per unit of harvest is $c(x_t) + d(S_t)$, where $c' > 0$, $c'' \geq 0$, $d' < 0$, and $d'' \geq 0$. The cost function in the foreign fishery is assumed to be $C^*(y_t) = c^*(y_t)y_t$ for a schooling fishery, such that the cost per unit of harvest is $c^*(y_t)$, and $C^*(y_t, S_t^*) = [c^*(y_t) + d^*(S_t^*)]y_t$ for a search fishery, such that the cost per unit of harvest is $c^*(y_t) + d^*(S_t^*)$, where $c^{*\prime} > 0$, $c^* \geq 0$, $d^{*\prime} < 0$, and $d^{*\prime\prime} \geq 0$. It is natural to assume that, for sufficiently small (but positive) stock sizes, the additional terms $d(S_t)$ and $d(S_t^*)$ would become large enough for further exploitation of the search fishery to become unprofitable.

These biological and economic differences between schooling fisheries and search fisheries can lead to striking results for the subgame perfect equilibrium harvest policy chosen by the domestic country in the first period of the two-period model developed in this paper. In the following section, the assumption of a nonzero minimum critical size of the foreign fish stock implies that the domestic country may choose a conservative harvest policy in the first period if it can induce biological collapse of the foreign fishery in the second period. In the section on search fisheries, the assumption of stock-dependent unit harvesting costs in the foreign fishery implies that the domestic country always chooses a conservative harvest policy in the first period in order to raise the foreign cost per unit of harvest in the second period. In the case of schooling fisheries, while there may or may not be sufficient incentive for the domestic country to induce biological collapse of the foreign fishery, in the case of search fisheries, there is always this incentive.

## Schooling Fisheries

Throughout this section, it is assumed that biological collapse of the domestic fishery in the second period cannot occur. This is because either efficient management of the domestic fishery implies that there will always be a domestic harvest in the second period, or because the initial size of the domestic fish stock is large enough to ensure a domestic harvest in the second period, or both. However, it is assumed that biological collapse of the foreign fishery in the second period can occur. This is because inefficient management of the foreign fishery need not imply that there will be a foreign harvest in the second period, or that the initial size of the foreign fish stock is not large enough to ensure a foreign harvest in the second period, or both. This assumption can be justified in the sense that the foreign fishery may have been under an inefficient management regime before the two periods examined here, or that the foreign fishery may have been exploited noncooperatively by several other countries before the two periods examined here.

In the two-stage, two-period model, the second period is linked to the first period through the effects of domestic and foreign harvests in the first period on the sizes of domestic and foreign fish stocks in the second period. Furthermore, in each period the second stage is linked to the first stage through the effects of the domestic harvest policy in the first stage on domestic and foreign harvests in the second stage. The model is solved for the subgame perfect equilibrium domestic harvest policy and harvest by domestic and foreign fishing industries in each period using the method of backward induction. Thus, consider first the second stage of the second period. The firms in the domestic fishing industry take the domestic harvest policy and the foreign harvest in this period as given, and the firms in the foreign fishing industry take the domestic harvest in this period as given. Using $p(x_t + y_t)$ to denote the world inverse demand curve (or the world price) for the fishery product in period $t$, such that $p' < 0$, the total profit of the domestic fishing industry in this period is

$$\Pi_2 = [p(x_2 + y_2) - c(x_2) - t_2]x_2 \tag{1}$$

where $t_2$ denotes the domestic harvest policy in the second period, $t_2 > 0$ implies a harvest tax, and $t_2 < 0$ implies a harvest subsidy. Using $\pi_2$ to denote the profit per unit of harvest, competition between domestic firms implies that the domestic harvest is determined by the condition

$$\pi_2 = p(x_2 + y_2) - c(x_2) - t_2 = 0. \tag{2}$$

If there is no biological collapse of the foreign fishery such that $S_2^* > 0$, then competition between foreign firms implies that the foreign harvest is determined by the condition

$$\pi_2^* = p(x_2 + y_2) - c_2^*(y_2) = 0. \tag{3}$$

If there is biological collapse of the foreign fishery such that $S_2^* = 0$, then there is no foreign harvest in the second period. These conditions determine the equilibrium domestic and foreign harvests $x_2(t_2)$ and $y_2(t_2)$ in the second period as functions of the domestic harvest policy in the second period. What are the effects of the domestic harvest policy chosen in the first stage on the domestic and foreign harvest in the second stage? Totally differentiating equations (2) and (3), respectively,

$$\begin{aligned} \pi_{2x_2} dx_2 + \pi_{2y_2} dy_2 + \pi_{2t_2} dt_2 &= 0 \\ \pi^*_{2x_2} dx_2 + \pi^*_{2y_2} dy_2 + \pi^*_{2t_2} dt_2 &= 0 \end{aligned} \tag{4}$$

where $\pi_{2x_2}\ p' - c' < 0, = \pi^*_{2y_2} = p' - c^{*\prime} < 0,\ \pi_{2t_2} = -1,\ \pi^*_{2t_2} = 0$, and $\pi_{2y_2} = \pi^*_{2x_2} = p' < 0$. As long as there is a foreign harvest in the second period, using the result that

$$D \equiv \pi_{2x_2}\pi^*_{2y_2} - \pi_{2y_2}\pi^*_{2x_2} = (p' - c')(p' - c^{*\prime}) - (p')^2 > 0 \tag{5}$$

it can also be shown that

$$x_{2t_2} \equiv \frac{dx_2}{dt_2} = \frac{p' - c^{*\prime}}{D} < 0 \tag{6}$$

and

$$y_{2t_2} \equiv \frac{dy_2}{dt_2} = -\frac{p'}{D} > 0. \tag{7}$$

If there is no foreign harvest in the second period, then it is obvious that $y_{2t_2} = y_2 = 0$, and it can also be shown that $x_{2t_2} = (p' - c')^{-1} < 0$.

These results indicate that the domestic harvest decreases as the domestic harvest policy becomes more conservative (as $t_2$ increases), and, as long as there is a foreign harvest, the foreign harvest increases as the domestic harvest policy becomes more conservative. The more conservative the harvest policy (the greater the tax per unit of harvest), the lower the domestic harvest. Also, the lower the domestic harvest, the greater the world price of the fishery product and the greater the foreign harvest. On the one hand, the effect of the domestic harvest policy on the domestic harvest implies that there is a direct efficiency-inducing role of the domestic harvest policy in the second period. On the other hand, the effect of the domestic harvest policy on the foreign harvest implies that there is also a strategic role of the domestic harvest policy in the second period, to enable the domestic country to raise its surplus from fishing through rent-shifting in the international market. These direct and strategic roles of the domestic harvest policy in the second period are examined next.

Consider the first stage of the second period. Subgame perfection implies that the domestic country anticipates the equilibrium in the second stage and chooses its harvest policy to maximize domestic surplus from fishing in the second period,[8]

$$G_2(t_2) = \left\{\pi_2\left[x_2(t_2), y_2(t_2), t_2\right] + t_2\right\}x_2(t_2). \tag{8}$$

Taking the total derivative of equation (8) yields

$$G_{2t_2} = [\pi_2 + t_2]x_{2t_2} + [\pi_{2x_2}x_{2t_2} + \pi_{2y_2}y_{2t_2} + \pi_{2t_2} + 1]x_2 \tag{9}$$

[8] From equation (1), the profit of the domestic fishing industry in the second period is equal to economic rent from fishing, $[p(x_2 + y_2) - c(x_2)]x_2$, minus government revenue from the harvest policy, $t_2x_2$. In equation (8), domestic surplus from fishing is defined as the profit of the domestic fishing industry plus government revenue from the harvest policy. This contribution of government revenue to domestic surplus cancels out with its deduction from the profit of the domestic fishing industry. Thus, choosing the domestic harvest policy to maximize domestic surplus from fishing in equation (8) is equivalent to choosing the domestic harvest policy to maximize domestic economic rent from fishing. Furthermore, equation (8) implicitly assumes that the domestic government understands how domestic surplus (or domestic economic rent) from fishing depends on the domestic harvest policy, through its direct and strategic effects on domestic and foreign harvests, shown in equations (6) and (7).

$$= t_2 x_{2t_2} + x_2(p' - c')x_{2t_2} + x_2 p' y_{2t_2}. \quad (10)$$

Setting $G_{2t_2} = 0$, and rearranging yields the optimal domestic harvest policy for the second period,

$$t_2 = -x_2(p' - c') - \frac{x_2 p' y_{2t_2}}{x_{2t_2}} > 0. \quad (11)$$

The first term in this expression represents the direct role of the domestic harvest policy to induce efficient domestic harvesting in the second period. The second term represents the strategic role of the domestic harvest policy to raise domestic surplus from fishing through the world price in the second period. Taking into account the minus signs, the first term is positive (indicating a harvest tax), and the second term is negative (indicating a harvest subsidy). However, it can be shown that the direct role of the domestic harvest policy dominates the strategic role, and the optimal policy in the second period is a (positive) harvest tax.[9] A similar result is derived by Dixit (1984) in his reciprocal markets model of export policies with any number of domestic and foreign firms, and is described by Brander (1995) as the standard terms of trade argument for government intervention in the presence of international market power. Think of the optimal domestic harvest policy shown in equation (11) as the “static optimum” in the second period.

Consider next the second stage of the first period. Once again, the firms in the domestic fishing industry take the domestic harvest policy and the foreign harvest in this period as given, and the firms in the foreign fishing industry take the domestic harvest in this period as given. Competition between domestic firms implies that the domestic harvest in the first period is, again, determined by the condition that average profit per unit of harvest is zero,

$$\pi_1 = p(x_1 + y_1) - c(x_1) - t_1 = 0 \quad (12)$$

the foreign harvest in the first period is, again, determined by the similar condition,

$$\pi_1^* = p(x_1 + y_1) - c^*(y_1) = 0 \quad (13)$$

and the effects of the domestic harvest policy on the domestic and foreign harvests in the first period are the same as those in the second period shown in equations (6) and (7). Moreover, as in the second period, the effect of the domestic harvest policy on the domestic harvest shown in equation (6) implies that there is a direct efficiency-inducing role of the domestic harvest policy in the first period. However, the effect of the domestic harvest policy on the foreign harvest shown in equation (7), and the potential effect of the foreign harvest in the first period on the size of the foreign fish stock in the second period, implies that there are also two strategic roles of the domestic harvest policy in the first period. They are: (*i*) to raise domestic surplus from fishing through the international market in the first period; and (*ii*) to induce even more foreign overfishing in the first period through the international market, thereby further raising domestic surplus from fishing in the second period. These direct and strategic roles of the domestic harvest policy in the first period are examined next.

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[9] Substituting equations (6) and (7) into equation (11) and rearranging yields $t_2 = x_2 p' c^{*\prime} / (p' - c^{*\prime}) + x_2 c'$, which is unambiguously positive.

Consider the first stage of the first period. Subgame perfection implies that the domestic country anticipates the equilibrium in the second stage of this period, and it also anticipates the equilibrium in the second period. This means that the domestic country takes into account the effect of its harvest policy in the first period on the size of the foreign fish stock in the second period through its effect on the foreign harvest in the first period. The more conservative the domestic harvest policy in the first period, the greater the equilibrium foreign harvest in the first period and the lower the size of the foreign fish stock in the second period. Since the second period equilibrium depends on whether or not biological collapse of the foreign fishery occurs, there are three possible cases to consider. The first of these is that the equilibrium foreign harvest in the first period is never large enough to result in biological collapse of the foreign fishery, no matter how conservative the domestic harvest policy in the first period is relative to the static optimum. The second possibility is that, even if the domestic harvest policy is no more conservative than the static optimum in the first period, the equilibrium foreign harvest in the first period is large enough to result in biological collapse of the foreign fishery. The third and most interesting possibility is that, for a sufficiently conservative domestic harvest policy in the first period relative to the static optimum, the equilibrium foreign harvest in the first period is large enough to bring about biological collapse of the foreign fishery.

The first two possibilities are not particularly interesting, since in both cases the subgame perfect equilibrium harvest policy in the first stage of the first period is

$$t_1 = -x_1(p' - c') - \frac{x_1 p' y_{1_{t_1}}}{x_{1_{t_1}}} \tag{14}$$

which is the same as the static optimum in the second period shown in equation (11). The only difference between the first and second possible cases is the presence or absence of the foreign fishery in the second period. However, the third possibility indicates that, under certain circumstances, the domestic country may face a tradeoff between domestic surplus in the first period and domestic surplus in the second period. On the one hand, choosing the domestic harvest policy in equation (14) leads to the maximum level of domestic surplus in the first period, but also accommodates a foreign harvest in the second period. On the other hand, choosing a sufficiently conservative harvest policy relative to that in equation (14) leads to relatively lower domestic surplus in the first period, but also results in biological collapse of the foreign fishery and a world monopoly for the domestic fishing industry in the second period.

Let $t_t^e$ denote the static optimum for period $t$ shown in equations (11) and (14). Let $t_1^m$ denote the domestic harvest policy in the first period that is just conservative enough to induce biological collapse of the foreign fishery in the second period, and let $t_2^m = -x_2(p' - c')$ denote the domestic harvest policy in the second period if there is a world monopoly for the domestic fishing industry in the second period. In this case, it is assumed that $t_1^m > t_1^e$ and $S_1^* - y_1^e \geq \underline{S}$ and $S_1^* - y_1^m < \underline{S}$, where $y_1^e$ and $y_1^m$ denote the corresponding equilibrium foreign harvests in the first period. These inequalities mean that biological collapse of the foreign fishery in the second period can only occur if the domestic country chooses the conservative harvest policy, $t_1^m$, instead of the static optimum, $t_t^e$, in the first period. Then the subgame perfect equilibrium for schooling fisheries involves the domestic country choosing one of two harvest policy regimes: $(t_1, t_2) = (t_1^e, t_2^e)$ or $(t_1, t_2) = (t_1^m, t_2^m)$. The domestic country chooses between these harvest policy regimes by determining which one yields the maximum present value of domestic surplus from fishing,

$$G(t_1, t_2) = \left\{\pi_1\left[x_1(t_1), y_1(t_1), t_1\right] + t_1\right\}x_1(t_1) + \delta\left\{\pi_2\left[x_2(t_2), y_2(t_2), t_2\right] + t_2\right\}x_2(t_2) \quad (15)$$

where $\delta$ represents the domestic discount factor between periods. Whether or not the domestic country has enough incentive to induce biological collapse of the foreign fishery in this case depends on the initial sizes of the domestic and foreign fish stocks and the domestic discount factor. This section concludes by providing the following proposition that strategic conservation by the domestic country in the first period to induce biological collapse of the foreign fishery in the second period can occur in subgame perfect equilibrium. The proof of this proposition is similar to the proof of the first proposition in Mason and Polasky (1994).

PROPOSITION 1 For the case of schooling fisheries, in subgame perfect equilibrium, the domestic country chooses a conservative harvest policy in the first period relative to the static optimum for sufficiently small initial sizes of the foreign fish stock.

PROOF Let $x_1^e$ be the first period equilibrium harvest by the domestic fishing industry if the domestic country chooses the domestic harvest policy $t_1^e$. Then, the first period equilibrium harvest by the foreign fishing industry is $y_1^e$, and, assuming biological collapse does not occur, the size of the foreign fish stock in the second period is determined by $S_2^* = f(S_1^* - y_1^e)$. If biological collapse of the foreign fishery does not occur, it must be that $S_1^* - y_1^e \geq \underline{S}$. However, there exists a critical level of $S_1^*$ such that $S_1^* - y_1^e = \underline{S}$, and the foreign fishery is on the verge of biological collapse. At this critical size of the foreign fish stock, if the domestic country decreases its harvest policy in the first period infinitesimally below $t_1^e$, then the domestic country induces just enough foreign overfishing in the first period to result in biological collapse of the foreign fishery in the second period. Doing so leads to a discontinuous increase in the present value of domestic surplus from fishing, since there would be only an infinitesimal decrease in domestic surplus in the first period. However, there would also be a world monopoly for the domestic fishing industry in the second period. For this critical size of the foreign fish stock, the domestic country would choose the conservative harvest policy over the static optimum for the first period in subgame perfect equilibrium.

## Search Fisheries

For search fisheries, since $\underline{S} = 0$, and unit harvesting costs decrease with the size of the fish stock, there is no potential for biological collapse of the foreign fishery, but there is potential for economic collapse. Depletion of the foreign fish stock in the first period could raise the foreign cost per unit of harvest in the second period enough for it to become unprofitable for there to be a foreign harvest in that period. This leads to the possibility that the domestic country may choose a harvest policy in the first period that is conservative enough to induce just enough foreign overfishing in the first period to result in economic collapse of the foreign fishing industry in the second period. In this section, however, a less dramatic outcome is considered in which it is shown that the domestic country always chooses a conservative harvest policy in the first period to induce even more foreign overfishing in the first period, whether or not it results in economic collapse of the foreign fishing industry in the second period.

Consider first the second stage of the second period. The profit of the domestic fishing industry is now

$$\prod_2 = \left[p(x_2 + y_2) - c(x_2) - d(S_2) - t_2\right]x_2 \tag{16}$$

and the domestic harvest is determined by the similar condition

$$\pi_2 = p(x_2 + y_2) - c(x_2) - d(S_2) - t_2 = 0. \tag{17}$$

The foreign harvest in this period is determined by the condition

$$\pi_2^* = p(x_2 + y_2) - c^*(y_2) - d^*(S_2^*) = 0. \tag{18}$$

These equations determine the equilibrium domestic and foreign harvests $x_2(S_2, S_2^*, t_2)$ and $y_2(S_2, S_2^*, t_2)$ in the second period as functions of the sizes of the domestic and foreign fish stocks and the domestic harvest policy in the second period. The effects of the domestic harvest policy and the domestic and foreign fish stocks in the second period are determined by totally differentiating equations (17) and (18), respectively,

$$\pi_{2x_2} dx_2 + \pi_{2y_2} dy_2 + \pi_{2S_2} dS_2 + \pi_{2S_2^*} dS_2^* + \pi_{2t_2} dt_2 = 0 \tag{19}$$
$$\pi^*_{2x_2} dx_2 + \pi^*_{2y_2} dy_2 + \pi^*_{2S_2} dS_2 + \pi^*_{2S_2^*} dS_2^* + \pi^*_{2t_2} dt_2 = 0$$

where $\pi_{2x_2}, \pi^*_{2y_2}, \pi_{2y_2}, \pi^*_{2x_2}, \pi_{2t_2}, \pi^*_{2t_2}$, and $D$ are the same as before and $\pi_{2S_2} = -d' > 0$, $\pi^*_{2S_2^*} = -d^{*\prime} > 0$, and $\pi_{2S_2^*} = \pi^*_{2S_2} = 0$. While $x_{2t_2}$ and $y_{2t_2}$ are the same as in equations (6) and (7), it can also be shown that

$$x_{2S_2} \equiv \frac{dx_2}{dS_2} = \frac{(p' - c^{*\prime})d'}{D} > 0 \tag{20}$$

and

$$y_{2S_2} \equiv \frac{dy_2}{dS_2} = -\frac{p'd'}{D} < 0. \tag{21}$$

These comparative static results indicate that the domestic harvest in the second period increases, while the foreign harvest in the second period decreases with the size of the domestic fish stock in the second period. On the one hand, the greater the size of the domestic fish stock, the lower the domestic cost per unit of harvest, and the higher the domestic harvest. On the other hand, the greater the domestic harvest, the lower the world price of the fishery product, and the lower the foreign harvest. Similarly, it can be shown that

$$x_{2S_2^*} \equiv \frac{dx_2}{dS_2^*} = -\frac{p'd^{*\prime}}{D} < 0 \tag{22}$$

and

$$y_{2S_2^*} \equiv \frac{dy_2}{dS_2^*} = \frac{(p' - c')d^{*\prime}}{D} > 0. \tag{23}$$

These four comparative static results do not influence the choice of domestic harvest policy in the second period, but they influence the choice of domestic harvest policy in the first period. As in the case of the schooling fishery, the effects of the domestic harvest policy on the domestic and foreign harvests shown in equations (6) and (7) imply that there is a direct role and a strategic role of the domestic harvest policy in the second period that do not depend on the size of the domestic or foreign fish stock. These roles are examined next.

Consider the first stage of the second period. The objective of the domestic government is to choose the level of domestic harvest in order to maximize domestic surplus in this period,

$$G_2(S_2, S_2^*, t_2) = \left\{\pi_2\left[x_2(S_2, S_2^*, t_2), y_2(S_2, S_2^*, t_2), S_2, t_2\right] + t_2\right\} x_2(S_2, S_2^*, t_2) \qquad (24)$$

and the solution is, once again, the static optimum in the second period,

$$t_2(S_2, S_2^*) = -x_2(p' - c') - \frac{x_2 p' y_{2_{t_2}}}{x_{2_{t_2}}} > 0 \qquad (25)$$

though the optimal domestic harvest policy is now written on the left-hand side as an explicit function of the domestic and foreign stock sizes in the second period.

Consider next the second stage of the first period. Once again, the firms in the domestic fishing industry take the domestic harvest policy and the foreign harvest in this period as given, and the firms in the foreign fishing industry take the domestic harvest in this period as given. Competition between domestic firms implies that the domestic harvest in the first period is, again, determined by the condition that average profit per unit of harvest is zero,

$$\pi_1 = p(x_1 + y_1) - c(x_1) - d(S_1) - t_1 = 0 \qquad (26)$$

the foreign harvest in the first period is, again, determined by the similar condition,

$$\pi_1^* = p(x_1 + y_1) - c^*(y_1) - d^*(S_1^*) = 0 \qquad (27)$$

and the equilibrium domestic and foreign harvests in the first period are $x_1(S_1, S_1^*, t_1)$ and $y_1(S_1, S_1^*, t_1)$. The effects of the domestic harvest policy on the domestic and foreign harvests in the first period are still the same as those shown in equations (6) and (7). However, given the comparative static results shown in equations (20), (21), (22), and (23), and given the growth functions for the domestic and foreign fish stocks, since the domestic harvest policy affects the domestic and foreign harvests in the first period, it also affects the domestic and foreign harvests in the second period. These first and second period effects imply that there are now several direct and strategic roles of the domestic harvest policy in the first period. These roles are examined next.

Consider the first stage of the first period. Subgame perfection implies that the domestic country anticipates the equilibrium in the second stage of this period, and that it also anticipates the equilibrium in the second period. This means that the domestic country takes into account the effect of its harvest policy in the first period on the size of the domestic and foreign fish stocks in the second period through its effect on the domestic and foreign harvests in the first period. The more conservative the domestic harvest policy in the first period, the lower (greater) the equilibrium domestic (foreign) harvest in the first period, the greater (lower) the size of the domestic (foreign) fish stock in the second period, and the lower (greater) the cost per unit of domestic (foreign) harvest in the second period. For search fisheries, since second period equilibrium always depends on the sizes of the domestic and foreign fish stocks in the second period, there is always an incentive for the domestic country to choose a conservative harvest policy in the first period relative to the static optimum derived above.

Given the equilibrium harvests in the second stage of the first period, $x_1(S_1, S_1^*, t_1)$ and $y_1(S_1, S_1^*, t_1)$, the domestic country chooses the first period harvest policy that yields the maximum present value of domestic surplus from fishing,

$$G(S_1, S_1^*, S_2, S_2^*, t_1) = \left\{\pi_1\left[x_1(S_1, S_1^*, t_1), y_1(S_1, S_1^*, t_1), S_1, t_1\right] + t_1\right\}x_1(S_1, S_1^*, t_1) \quad (28)$$
$$+ \delta\left\{\pi_2\left[x_2(S_2, S_2^*), y_2(S_2, S_2^*), S_2, t_2(S_2, S_2^*)\right] + t_2(S_2, S_2^*)\right\}x_2(S_2, S_2^*)$$

subject to $S_2 = f[S_1 - x_1(S_1, S_1^*, t_1)]$ and $S_2^* = f\left[S_1^* - y_1(S_1, S_1^*, t_1)\right]$. Taking the derivative of equation (28) with respect to $t_1$ yields

$$G_{t_1} = [\pi_1 + t_1]x_{1t_1} + [\pi_{1x_1}x_{1t_1} + \pi_{1y_1}y_{1t_1} + \pi_{1t_1} + 1]x_1 + \delta[\pi_2 + t_2]x_{2S_2}S_{2x_1}x_{1t_1} \quad (29)$$
$$+ \delta[\pi_{2x_2}x_{2S_2} + \pi_{2y_2}y_{2S_2} + \pi_{2S_2} + \pi_{2t_2}t_{2S_2} + t_{2S_2}]S_{2x_1}x_{1t_1}x_2$$
$$+ \delta[\pi_2 + t_2]x_{2S_2^*}S^*_{2y_1}y_{1t_1} + \delta[\pi_{2x_2}x_{2S_2^*} + \pi_{2y_2}y_{2S_2^*} + \pi_{2t_2}t_{2S_2^*} + t_{2S_2^*}]S^*_{2y_1}y_{1t_1}x_2$$

$$= t_1x_{1t_1} + x_1(p' - c')x_{1t_1} + x_1p'y_{1t_1} + \delta f'x_2d'x_{1t_1} + \delta f'x_2d^{*\prime}\left(\frac{y_{2t_2}}{x_{2t_2}}\right)y_{1t_1} \quad (30)$$

which can be simplified and rearranged to yield the optimal domestic harvest policy in the first period,

$$t_1 = -x_1(p' - c') - \frac{x_1p'y_{1t_1}}{x_{1t_1}} - \delta f'x_2d' - \delta f'x_2d^{*\prime}\left(\frac{y_{2t_2}}{x_{2t_2}}\right)\left(\frac{y_{1t_1}}{x_{1t_1}}\right) > 0. \quad (31)$$

Once again, the first term in equation (31) represents the direct role of the domestic harvest policy to induce static efficiency in the first period. The second term represents the strategic role of the domestic harvest policy to raise domestic surplus from fishing through the world price in the first period. These two terms taken together are just the usual static optimum in the first period. The third term represents the direct role of the domestic harvest policy to induce dynamic efficiency in the first period; the lower the domestic harvest in the first period, the larger the size of the domestic fish stock and the lower the domestic cost per unit of harvest in the second period. Finally, the last term represents the strategic role of the domestic harvest policy to induce foreign overfishing in the first period; the lower the domestic harvest in the first period, the larger the foreign harvest in the first period, the smaller the size of the foreign fish stock and the larger the foreign cost per unit of harvest in the second period. This enables the domestic country to even further raise its surplus from fishing through the world price in the second period.

Since the last two terms in equation (31) are both positive, it is clear that the subgame perfect equilibrium harvest policy is larger (more conservative) than the static optimum in the first period. The opportunity for the domestic country to raise its surplus from fishing at the expense of the foreign fishing industry in the second period always provides an incentive for the domestic country to choose a conservative harvest policy in the first period, even if economic collapse of the foreign fishery in the second period cannot occur. These results prove the following proposition that summarizes this result.

Proposition 2 For the case of search fisheries, in subgame perfect equilibrium the domestic country always chooses a conservative harvest policy in the first period relative to the static optimum, regardless of the initial size of the foreign fish stock.

## Summary and Extensions

This paper has suggested that fisheries trade in the presence of international market power and divergent national fisheries management regimes could have unexpected consequences for world fisheries. The results of the two-stage, two-period model developed here were based on the assumption that two countries have international market power and an identical fisheries product at the level of their fishing industries. The results were also based on the assumption that the domestic country uses a harvest policy in each period to regulate its fishing industry, while the foreign fishing industry is unregulated. Two types of fisheries were considered. In the case of schooling fisheries, it was found that the domestic country may choose a conservative harvest policy in the first period if it can induce biological collapse of the foreign fishery in the second period. In the case of search fisheries, it was found that the domestic country always chooses a conservative harvest policy in the first period, even if it cannot induce economic collapse of the foreign fishing industry in the second period.

An important extension to the model developed in this paper would be to assume that the product of the domestic and foreign fishing industries is consumed in domestic and foreign markets instead of the international market. The potential degradation or destruction of the foreign fishery in the second period would then have a negative impact on consumer surplus in the domestic market for the fishery product. In this case, depending on whether the domestic country imports or exports the fishery product, the domestic country could choose a harvest policy in the first period that induces either the strategic enhancement (or preservation) of the foreign fishery in the second period or its strategic degradation (or destruction). Another important extension that follows from the previous extension would be to allow for the possibility of strategic behavior by the foreign country in the form of trade policy (such as an export quota, an import quota, or a tariff, depending on whether the foreign country imports or exports the fishery product) in response to strategic regulation of the domestic fishing industry.[10] In this case, the possibility of retaliation by the foreign country would have to be taken into account by the domestic country when it chooses its harvest policy.

[10] As noted in footnote 2, inefficient management of the foreign fishery could be the result of prohibitively high management and enforcement costs. However, the foreign country could still resort to trade policy as an indirect tool for regulation of the foreign fishing industry and as a strategic tool in its trade relations with the domestic country.

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