Transboundary Renewable Resource Management and Conservation Motives

Missios, Paul and Plourde, Charles

Ryerson University

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PAUL C. MISSIOS,

Department of Economics

York University

and

CHARLES PLOURDE,

Department of Economics,

York University.

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I. Introduction

Although the issue of the optimal management of jointly-exploited renewable resources, such as many transboundary fish stocks, is not necessarily new, it is certainly current given the recent conflicts between Canada and the European Union over turbot and between Canada and the United States over Pacific salmon, as well as the seemingly endless conflict in the North Atlantic fishery over cod. If countries were identical in every way, this management would likely be trivial as all countries would ideally agree on the optimal steady state biomass level, and thus agree on harvest shares and on the optimal annual harvest of the stock. Conflicts arise, however, when there are differences between countries. In previous studies, such as Munro (1979), these differences have centred around divergences in perceptions of the social discount rate and in harvesting costs across countries. Discount rates have typically been employed to compare differences in countries' views on conservation, as low discount rates imply a greater emphasis on future returns, so that countries with such rates would prefer to harvest more in the future than higher discount rate countries and would therefore be more "conservationist." While this view may in part describe this motivation, clearly other social, political and moral reasons for conservation exist, and it is this issue which is addressed in this paper. Observation suggests that some countries are interested in conservation of fish stocks for reasons other than future profit, and frequently, the countries which are more conservative have some vested interest in conservation of a particular fish stock itself, as in the case where a country has a significant domestic industry which is dependent on that fish stock. Often, the more conservationist country borders on the resource and may have a fishing fleet suitable for fishing close to home but unsuitable for global harvesting, so that the survival of the fish stock is vital to the industry. A foreign country fishing armada usually has alternative fishing possibilities so that depletion of a particular stock is of less consequence, and therefore may have an incentive to ignore the conservation of the resource and move on to other areas. In this paper, we model a duopolistic situation in which one country, denoted the home country, has a "conservation motive," preferring a higher stock independently of the level of the harvest, and another country, the foreign country, which has no such motive, and thus is simply concerned with a discounted flow of profits derived from the harvest. Countries are assumed to contemplate a cooperative agreement, as it is generally accepted that cooperation is more desirable with respect to both conservation (higher steady state stock levels) and social welfare of all parties.[1] This study is focussed on the optimal steady state fish stock level, and hence on the steady state total allowable harvest (TAC), and not on how such a harvest is divided.[2] The economics of the sharing of this total harvest requires the relatively straight-forward application of Nash bargaining concept. However, such an analysis would require the specification of "threat points" or non-cooperative payoffs. For examples of optimal sharing rules, see Vislie (1987) which provides a dynamically-consistent (self-enforcing) agreement assuming that the payoffs in the absence of a cooperative settlement are equal, or Ferrara and Missios (1995) which finds the optimal dynamically-

[1]Levhari and Mirman (1980) show this in a non-cooperative model where the two countries act as Cournot duopolists. Plourde and Yeung (1989) find that this result also applies to situations in which there are more than two countries competing for the same stock.

[2] The division of the harvest can be assumed to be determined prior to the negotiation of the TAC.

consistent sharing rule accounting for potential differences in non-cooperative payoffs through an extension of Vislie's model. Dynamically-consistent solutions such as these are preferable to "binding contract" models of Munro's type, which require perfect enforcement of quotas whereas in reality this may be impossible or excessively costly. In the following sections, the impacts of the harvest sharing rule as well as differences in the discount rates on the steady state fish stock are analyzed and briefly compared to two current conflicts - the Canada-EU turbot and Canada-US salmon disputes - in an attempt to explain the practices observed in allowable catch trends and make predictions regarding future agreements.

II. The Model

As in Munro (1979), we consider two countries facing a world demand for harvested fish that is infinitely elastic, implying a parametric price, *p*. In each period t, the two countries bargain over the division of their combined harvest, h_t, with α as the share of country one (the home country) and $(1-\alpha)$ as the share of country two (the foreign country), where $0 \leq \alpha \leq 1$. This is in contrast to Munro's model in which countries bargain over the weight given to their objective functional in the joint maximization problem, and not over harvest shares. From the observation of such international fishery management coalitions such as the North Atlantic Fishery Organization (NAFO), it appears more likely that countries in fact bargain over shares of the total allowable catch. For the same reason, in our model the two countries negotiate a binding agreement (as in Munro). Let x_t be the fish biomass at time t, so that the change in the fish stock is the natural growth function, $F(x)$, less the total harvest:

$$\dot{x}_t = F(x_t) - h_t.$$

From here forward, we will ignore time subscripts except when their inclusion is informative.

For convenience of exposition, we will assume that the biological growth function can be

$$F(x) = \lambda x - \varepsilon x^2.$$

expressed as the Schaeffer-Lotka variation

For simplicity we also assume that the countries both have a constant average cost of extraction equal to *c*. Finally, let the instantaneous social discount rates for the home and foreign countries be δ_1 and δ_2, respectively.

The home country receives instantaneous social benefits from both the harvest and the

$$\int_0^\infty \beta e^{-\delta_1 t} U(h_t, x_t) dt,$$

level of the fish stock, so that its objective functional is:

where $U_2 = \partial U / \partial x \geq 0$. If $U_2 > 0$ then the home country has the above mentioned conservation motive, deriving utility from the level of the fish stock, but if $U_2 = 0$ then there is no such motive. The foreign country's objective functional is the discounted net profit from its share of the harvest:

$$\int_{0}^{infinity} (1-\beta)e^{-\delta_2 t}[p-c]h_t\,dt.$$

$$\beta\int U(h,x)e^{-\delta_1 t}\,dt + (1-\beta)\int [p-c]h \bullet e^{-\delta_2 t}\,dt$$

$$\dot{x} = \lambda x - \varepsilon x^2 - h,$$

$$0 \le h_t \le h_{\mathrm{MAX}},$$

$$x_t \ge 0,$$

The problem is then to maximize the sum of the objective functionals

subject to the constraints
and,
where h_{MAX} is the maximum possible harvest in any period, determined by physical catch constraints.

This maximization can be constructed as an optimal control problem with the control variable h_t, the state variable x_t and the co-state variable q:

$$\mathrm{H} = \beta U(h,x)e^{-\delta_1 t} + (1-\beta)[p-c]h \bullet e^{-\delta_2 t} + q \bullet e^{-\delta_1 t}(\lambda x - \varepsilon x^2 - h)$$

$$H = e^{\delta_1 t}\mathrm{H} = \beta U(h,x) + (1-\beta)[p-c]h \bullet e^{-\delta t} + q(\lambda x - \varepsilon x^2 - h)$$

$$\frac{\delta H}{\delta h} = \beta U_1(h,x) + (1-\beta)[p-c]\, e^{-\delta t} - q = 0,$$

which can be transformed into the present value Hamiltonian,
where $\delta=\delta_2-\delta_1$. Application of the Maximum Principle yields the optimality conditions,

$$\dot{q} = \delta_1 q - [\,\beta U_2 + q\lambda - 2\varepsilon q x]$$

and the transversality condition,

$$\lim_{T \to infinity} (q \bullet x_T \bullet e^{-\delta_1 T}) = 0.$$

$$\tilde{x} = \frac{\lambda - \delta_1}{2\varepsilon} + \frac{\beta U_2(h,x)}{2\varepsilon q}.$$

In the steady state, q=x=0, so the steady state fish stock is found to be
Using the first optimality condition for q and substituting into the second condition, this steady state can be rewritten as

$$\tilde{x} = \frac{\lambda - \delta_1}{2\varepsilon} + \frac{\beta U_2(\tilde{h},\tilde{x})}{2\varepsilon[\beta U_1 + (1-\beta)[p-c]e^{-\delta t}]}.$$

Notice, that if $U_2=0$, the steady state stock level is independent of the harvest shares given that the growth parameters λ and ε, as well as the discount factor δ_1, are constants. Thus, in the situation where the home country has no conservation motive and therefore acts in the manner of the foreign country, the steady state fish stock is independent of the division of the harvest, as found by Munro.[3] However, when there does exist a conservation motive in the management preferences of the home country (U_2 is not zero), this independence does not exist, as can be

$$\frac{\delta\tilde{x}}{\delta\beta} = \frac{U_2[2\varepsilon\beta U_1 + 2\varepsilon(1-\beta)[p-c]e^{-\delta t}] - \beta U_2[2\varepsilon(U_1 - [p-c]e^{-\delta t}]}{[2\varepsilon(\beta U_1 + (1-\beta)[p-c]e^{-\delta t})]^2},$$

shown through the derivative with respect to the harvest share β:

which simplifies to

$$\frac{\delta\tilde{x}}{\delta\beta} = \frac{U_2[p-c]e^{-\delta t}}{2\varepsilon[\beta U_1 + (1-\beta)[p-c]e^{-\delta t}]^2},$$

which is positive as long as U_2 is positive. This result implies that in the presence of a conservation motive for one country, the steady state biomass level is higher when the harvest

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[3] Even if there is no conservation motive for the home country, the Munro result of a "bang-bang" solution will be replicated here only if the utility function of the home country is linear in h.

share of that country increases, a finding which is intuitively appealing.[4]

III. Impact of Differences in Discount Factors

A higher discount factor and thus more emphasis on future returns, as mentioned previously, has been employed to differentiate between ✌more✍ and ✌less✍ conservative countries. While it is true that a higher discount factor does implicitly indicates a desire to receive a lower harvest today in return for a larger harvest in the future, we have shown that other more benevolent motives for conservation can result in a higher fish stock than without such motives independently of differences in discount factors. In other words, the steady state stock will be higher if one country has a conservation motive even if the discount factors, or equivalently discount rates, of the home and foreign countries are identical (that is, even if ⌧=0). Despite this fact, it is necessary to examine the case in which the differences exist between the discount factor of the home and that of the foreign country, as it is quite unlikely that all countries have

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[4]This analysis can be extended to a "Home-Home" model where both countries have a conservation motive. The joint maximization problem would become

$$\int \beta U^{1}(h,x)e^{\delta_1 t}\,dt + \int (1\beta)U^{2}(h,x)e^{\delta_2 t}\,dt,$$

subject to the above constraints, where U^i is the social benefit function of country *i*. In this case, the steady state stock level, from the optimality conditions, would be

$$\tilde{x} = \frac{\lambda\delta_1}{2\varepsilon} + \frac{\beta U_2^1 + (1\beta)U_2^2 \bullet e^{\delta t}}{\beta U_1^1 + (1\beta)U_1^2 \bullet e^{\delta t}}.$$

Notice, if the two countries were to have the same social benefit functions and discount rates (i.e., the two countries were identical), the steady state would be independent of [illegible], as would be expected.

identical valuations regarding future harvests or views on risk or uncertainty. We find that the

$$\frac{\partial \tilde{x}}{\partial \delta_1} = \frac{1}{2\varepsilon} \frac{\beta U_2(\tilde{h},\tilde{x})t[(1\beta)(pc)]\, e^{\delta t}}{2\varepsilon[\,\beta U_1(\tilde{h},\tilde{x})+(1\beta)(pc)e^{\delta t}\,]^2} < 0$$

steady state fish stock is increasing in ⌧, since ⌧=⌧$_2$-⌧$_1$ and

$$\frac{\partial \tilde{x}}{\partial \delta_2} = \frac{\beta U_2(\tilde{h},\tilde{x})t[(1\beta)(pc)]\, e^{\delta t}}{2\varepsilon[\,\beta U_1(\tilde{h},\tilde{x})+(1\beta)(pc)e^{\delta t}\,]^2} > 0.$$

and

So, as the difference between the discount factors of the foreign country and the home country becomes larger, the steady state stock becomes larger, and consequently, the combined harvest of the two countries becomes smaller. This is analogous to saying that increases in the discount factor of the home country holding the discount factor of the foreign country constant, or decreases in the discount factor of the foreign country holding the discount factor of the home country constant, result in a lower steady state fish stock, a less conservative outcome. This at first seems counter-intuitive: if we compare the case where the more conservative (home) country■s discount factor is larger than that of the less conservative foreign country to when the two factors are equal, we find that despite the fact the more conservative country becomes even more ✌conservationist,✍ a less conservative outcome ensues. However, this ✌one country only✍ perspective is deceiving. In the above scenario, it is true that the country with the conservation motive becomes even more conservative, the foreign country is *relatively* less conservative, and therefore there is an even greater conflict between the management preferences of the two countries, and it appears that this conflict is the source of the lower steady state. This may be more easily seen in the opposite case in which the discount factor of the foreign country rises relative to the home country's discount factor, which leads to a higher steady state stock level. Here, both countries desire some level of conservation, but for different reasons: the foreign country wants conservation of the stock because it is more future-oriented and greater conservation today implies larger harvests in the future, and the home country seeks conservation simply because it prefers more of the resource for social or political reasons as well as for future harvests.

IV. A Brief Application to the Current Turbot and Salmon Disputes

In early 1995, a "fish war" which gained much attention erupted between the European Union and Canada over a member of the flounder family called turbot. The dispute occurred in an area off the coast of Canada (but outside the 200-nautical mile limit) known as the "nose" and "tail" of the Grand Banks of Newfoundland, where European vessels, primarily Spanish and Portuguese, fished well above the quota set by the 15-country NAFO for the European Union. In 1995, the European Union received a quota of 3,400 tonnes, 12.6 percent of the 27,000 total allowable catch. Canada and the European Union finally reached an agreement that was extended to cover all of the 15 members of NAFO, in which the total allowable catch was set at 20,000 tonnes with Canada receiving a share of 15 percent (down from 60 percent) and the European Union receiving a share of 55 percent. The total allowable catch has been falling steadily, from over one hundred thousand tonnes in 1989 to just twenty thousand tonnes in 1996, a detail which parallels the significant decline of turbot stocks in recent years to dangerous levels.[5] In light of the falling turbot stocks from overfishing above the set international quotas, Canada likely has an incentive to conserve turbot stocks (or a conservation motive for the ✌home✍ country), particularly as turbot has gained a substantial importance to the Canadian Atlantic fishery given the recent devastation of cod and other north Atlantic stocks. Further, until 1996, Canada has received a share of the total allowable catches above sixty percent (in our model, a share 👓 higher than one half). Using these two facts, our model predicts a high steady state fish stock, and combined with the recent overfishing, suggests that the total allowable catch should be low relative to the 1980s when the conservation of turbot stocks was of a much lesser concern, and so is consistent with the above mentioned observed fall in total allowable catches in the 1990s. However, this may be partially offset by the fact that the European Union may be more present-oriented (i.e. may have a lower discount factor) relative to Canada, which has markedly lower interest rates than in Europe.[6]

While it may be reasonable to accept that Canada and the European Union have different views on the conservation of stocks off the Canadian coast, it is not so easy to accept for the Pacific salmon dispute between Canada and the United States. The present salmon conflict, which began over a century ago and recurringly flares up from time to time, contains elements which suggest that both countries have a significant interest in the long-term viability of the

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[5] Estimates of the stock size of turbot vary substantially, but most would be consistent with the view that turbot are in danger of extinction if the overfishing that occurred in the 1980s and early 1990s is to continue.

[6] For example, annual government treasury bill rates, in the period from 1985 to 1994, ranged from 4.84% to 12.81% in Canada but ranged from 8.03% to 14.17% in Spain (and were on average 2.3 percent higher in Spain). Source: IMF International Financial Statistics (CD-ROM).

Pacific salmon fishery. Of the four major Pacific salmon species, pinks and sockeye mainly spawn in the Canadian rivers of British Columbia (particularly the Fraser River), and cohos and chinooks mainly spawn in the American Rivers of Washington and Oregon (especially the Columbia River). The dispute arises from American catches of fish spawned in Canada as they pass through American waters and from Canadian catches of fish spawned in the United States as they pass through Canadian waters. Sockeye and chinooks are the most valuable species of the above four, the first to Canada and the second to the United States. As an obvious result, both sides should be concerned with the conservation of the salmon fishery. In this case, the variation of the model where both countries have a conservation motive must be used, and accordingly, it is expected that the agreement reached between Canada and the United States would include a low total allowable catch.[7] Given the past overfishing by fishermen of both countries in the past despite various treaties meant to prevent such occurrences, the sharing rule should be of the self-enforcing type of Vislie, or Ferrara and Missios.

Conclusion

A simple theoretical model of transboundary fishing conflicts in which one country has an a priori incentive to conserve was presented to analyze the effect of such a conservation motive on the steady state fish stock, as well as to examine how this stock is affected by the sharing rule negotiated between two countries. In contrast to previous studies, this paper has investigated the determination of the total allowable catch through the use of the steady state, and

[7]Traditional legal rights of the Native peoples of both the United States and Canada will complicate this issue.

not the division of a given harvest.

The presence of a conservation motive serves to increase the steady state fish stock level, as do increases in the negotiated share of the country with such a motive. The model does possess some predicative power, being consistent with the observation of the recent decline in total allowable catches of turbot set by NAFO in the dispute between Canada and the European Union, and being useful in deducing the justification of such actions. Despite its simplicity, the model presented here adds necessary reality to previous models of jointly-exploited fish stocks, and can easily be extended beyond fishery management to that of other transboundary renewable natural resources.

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Abstract:

A simple two-country theoretical model of transboundary fishing conflicts in which one country has an incentive to conserve the fish stock in addition to being profit-maximizing is presented to examine the effect of such a conservation motive on the stock level in the steady state and to analyze how this stock level is affected by the division of the harvest. A formal model is utilized to show that a conservation motive of one or both countries serves to increase the stock level and that this level is increasing in the harvest share of the country with the motive. A brief application to the Canada-European Union turbot and Canada-United States salmon disputes suggests consistency between the model and reality.

Keywords:

Conservation, economic theory, natural resource management, game theory, optimal control theory, fisheries managment, turbot, salmon.