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Trade and fisheries subsidies[†]

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Abstract. World Trade Organization members included fishery subsidies in the Doha round of trade negotiations, which subsequently stalled. This paper develops a simple model to show why prospects for a deal on fisheries subsidies may be difficult. Typically international spillover effects create incentives among exporters to negotiate reductions in subsidies: one country's subsidy worsens other exporters' terms of trade. These incentives may not exist in fisheries for 3 reasons. First, if fisheries are severely depleted, one country's subsidy reduces its long run supply of fish, raising prices and benefiting other fish exporting countries. Second, if governments use other policies to manage fish stocks, then changes in subsidies may not affect harvests and hence may not generate international spillover effects. And third, even if governments were compelled to reduce fishery subsidies, there may be little real effect because governments would be motivated to weaken other regulations targeting the fish sector.

Keywords: Fishery subsidies, international trade, trade agreements

JEL- Classification: F18, F53, Q22, Q27

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1. Introduction

Fisheries are heavily subsidized in many parts of the world and yet many fisheries are being harvested at a rate that is unsustainable. This suggests that there ought to be potential for international agreements to curtail the use of subsidies; and indeed the Doha conference launched negotiations to clarify and improve World Trade Organization (WTO) disciplines on fishery subsidies. However the negotiation process has stalled.[1] This paper develops a simple model of trade in fisheries, building on Bagwell and Staiger's (2001a; 2001b) work on international trade and subsidy agreements, to explore reasons why achieving an agreement to reduce subsidies may be difficult.

The coexistence of depleted fisheries and extensive subsidization is well documented. Worm et al. (2009) report that 63% of assessed fish stocks worldwide require rebuilding, and the FAO (2011) reports that approximately 87% of the world fish stocks are fully exploited or overexploited. As depletion rates have increased, fishery subsidies have grown substantially, particularly in Europe and the East Asia. They reached levels of US$ 30-34 billion per year in the period 1995-2005 (Sumaila et al., 2006).[2] The majority of these fishery subsidies are non-fuel subsidies, 49% of them being provided by 38 developed countries and 51% by 103 developing countries.[3] The largest subsidies are provided by India (US$ 4.3 billion), Japan (US$ 4.0 billion) and the European Union (US$ 3.0 billion) respectively (Khan et al., 2006). About two-thirds of the total subsidies (US$ 20 billion) are estimated to be of the type that result in an increase in fishing effort.

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[1] The Hong Kong Conference (2005) attained a broad agreement on strengthening those disciplines, including the prohibition of certain forms of fishery subsidies that contribute to overcapacity and overfishing. This conference led to a new Annex VIII to the Agreement on Subsidies and Countervailing Measures. However the negotiation process had stalled and achieving agreements to reduce subsidies has been difficult. Only a 'road map' of key issues rather than a new draft text has emerged in December 2008 (Young, 2009).

[2] There have been other estimates of fisheries subsidies worldwide: Milazzo (1998), OECD (2006), and Khan et al. (2006).

[3] OECD (2006) offers a different categorization of fisheries subsidies provided in 2003: management, research, and enforcement: 38.8%; infrastructure: 35%; decommissioning schemes: 6.7%; income support: 6.7%; investment and modernization: 3.2%; access payments: 3%; and other cost-reducing transfers and direct payments (including price support schemes): 7%.

Many analysts argue that the subsidization is contributing to the high rate of fisheries depletion (see for example, Sumaila et al., 2007). Why then is it so difficult to negotiate agreements to reduce subsidies?

We develop a model of endogenous fisheries subsidies in which governments motivated by political objectives implement subsidies, perhaps in conjunction with other resource management tools (such as restrictions on season length, fishing gear, etc.). We focus on fish stocks that lie entirely within the jurisdiction of single countries. There are well-known international coordination issues that arise from transboundary fish stocks that have been considered elsewhere. Here we wish to focus on purely trade-related issues and hence consider local fish stocks. For most of the paper we consider fish exporting countries, although we briefly discuss the case of importers. We assume that governments care about employment in the fishery in addition to resource rents. With a sufficiently strong employment motive, governments will subsidize the fishery. We take government preferences as given and focus on the question of whether (given their political objectives) there are incentives to negotiate reductions in subsidies. We embed this structure in an international trade model that allows us to analyze the spillover effects of subsidies across countries.

In the standard trade agreement literature (such as Bagwell and Staiger, 2001a) the key channel via which countries are linked is world prices. Domestic policies such as subsidies create global price spillover effects, and this creates incentives to negotiate, regardless of what government objective functions look like. Bagwell and Staiger (2001b) consider politically motivated governments that use agricultural subsidies to redistribute income to farmers. Each country's subsidy generates increased output, which lowers world prices, making it harder for other governments to achieve their redistribution objectives. They therefore show how even politically motivated governments have an incentive to implement an agreement to limit their use of subsidies to curtail the price spillover effects. In the case of fisheries, this channel also exists, but will behave much differently because of resource depletion effects. Because depleted fisheries have backward bending supply curves, an increase in one country's subsidy can lead to reductions in long run harvest rates, which raises prices, thus benefiting other exporting countries. Put another way, an increase in one country's subsidy can lead to positive price spillover effects for other countries, which is opposite to the usual presumption in global subsidy negotiation models. Hence the incentives to negotiate an agreement to internalize price spillover effects in seriously depleted fisheries may either be non-existent or perverse.

Not all subsidized fisheries are seriously depleted. We therefore also consider subsidized fisheries that are effectively regulated and show that there is limited potential for negotiated agreements to reduce subsidies in this case as well. We consider a scenario where governments use both subsidies and other regulatory instruments to achieve their political objectives. We find that in some cases the cooperative equilibrium yields the same outcome as the non-cooperative equilbrium so that there is no incentive to negotiate an agreement to reduce subsidies. In other cases, exporters would reap terms of trade benefits if they could commit to reducing harvest levels, but an agreement to reduce subsidies may not accomplish this because it creates incentives for governments to weaken other forms of regulation to maintain harvesting levels. These "policy substitution" effects impact most trade agreements (such as the increased use of nontariff barriers in response to tariff reductions). However, in the context of a renewable resource, we show that policy substitution can render an agreement to reduce subsidies completely ineffective because the ecological constraints on the fishery provide a binding cap on harvest levels, and this can essentially make each government's desired harvest levels unresponsive to changes in price or subsidy constraints.

Previous theoretical work has considered the effects of fisheries subsidies, but has not explicitly focussed on the incentives to negotiate that we emphasize.[4] Clark et al. (2005)

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[4] There is also a literature documenting the effects of existing subsidies. Munro and Sumaila (2002) estimate that one-third of the total fisheries subsidies paid by governments for North Atlantic fisheries are buyback subsidies. Sumaila et al. (2010) find that bottom trawl fleets operating in the high seas would make negative profits in the absence of subsidies. Carvalho et al. (2011) use a dynamic CGE model to assess the impact of the fisheries subsidies removal on the small island economy of Azores.

analyze the potential negative effects of anticipated buyback subsidies on economic performance and on resource conservation. Jinji (2012) considers potential perverse effects of an exogenous reduction in subsidies when fishers' labour supply is endogenous. He shows how a reduction in subsidies aimed at income support can lead to an increase in labour supply to the fishery, leading to a reduction in the steady state fish stock. Neither of these papers considers spillover effects across countries or incentives to negotiate.

There is a large literature on shared fisheries that focuses on cross-country stock externalities, which is a different channel than we highlight (see for instance, Munro (1979), Copeland (1990), Munro (2007), Bulte and Damania (2005), Pintassilgo et al. (2010) and Rus (2012)). A couple of papers on shared fisheries consider subsidies. Ruseski (1998) studies a two-stage non-cooperative game to explain the persistence of subsidies for two countries having fleets that exploit international fish stocks. The rationale for the existence of subsidies here is strategic rent shifting. Quinn and Ruseski (2001) use a similar model with heterogeneous countries to highlight the strategic entry-deterrence role of domestic effort subsidies. A country having an effort cost advantage may provide a positive effort subsidy to its domestic fleet in order to deter entry by rival foreign fleets. These papers help to explain the persistence of subsidies in high seas fisheries where there is a threat of foreign fleet entry. However they do not explain the persistence of large subsidies for national fisheries.

In what follows, we set out the model and its assumptions in Section 2. Section 3 presents the results when politically motivated governments use only subsidies. Section 4 analyzes cases where both subsidies and fishery regulations are available. Section 5 and Section 6 respectively discuss how our results would differ for fisheries with low depletion potential and for fish producing countries that are net importers of fish. Section 7 summarizes our main results and draws some policy conclusions.

2. The Model

We develop a simple model in which governments care about both rents and employment in the fishery sector. Hence governments have two distinct motives, a conservation motive and an employment motive. This requires the use of two instruments to maximize the objective function. Government policy instruments include taxes/subsidies, and a set of regulations that raise the cost of fishing.[5] In fact, the employment motive can conflict with the conservation motive: pressure to maintain employment in the fisheries sector can lead to stock depletion. In this case, the fish stock can be protected from the depleting effects of subsidies by introducing additional regulations that lower fishing productivity. We assume that individual harvest quotas are not available - this may be justified by appealing to monitoring costs and political constraints.[6] We focus on the steady state and implicitly assume that the discount rate approaches zero.[7] International agreements are long-term commitments, and a focus on steady states allows us to highlight long run issues in a very simple way. The case where the discount rate approaches zero provides a useful benchmark because it implies that (given the behavior of their trade partners) governments will want to choose rules that maximize sustained well-being as defined by their employment-weighted objective function. This will allow us to highlight difficulties in reaching subsidy agreements that arise even in cases where governments are not short-sighted.

We consider a non-cooperative equilibrium in which governments' objective functions depend on steady state values. This abstracts from transitional dynamics and intertemporal strategic effects, but its relative simplicity allows us to highlight several strategic issues that distinguish subsidies in fisheries from subsidies in other commodities.

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[5] If efficiency is the sole objective, then in our simple framework the use of additional regulations is unnecessary and efficiency-reducing. In Section 3, we will show that the first best can be achieved by fully internalizing the harvest externality with a tax on fishers.

[6] In practice, Arnason (2012) estimates that the fraction of total global harvest covered by individual transferable quotas (ITQs) has recently grown to almost 25%; which nevertheless means that about 3/4 of the global harvest is not covered by such quotas. The fraction of fisheries covered by ITQs is harder to estimate. In the Costello et al. (2008) sample of 11,135 commercial fisheries, only 121 were managed by ITQs. The number has grown since then but still represents a small fraction of the total. Most developing countries have not adopted ITQs, although there are a few exceptions such as Namibia and Mozambique for some of their fisheries. We therefore chose to focus our analysis on fisheries not covered by ITQs. However, Sections 4 and 5 of the paper consider fisheries subject to regulations in addition to subsidies.

[7] This approach has also been taken in other work analyzing trade and fisheries such as Brander and Taylor (1997).

This approach of analyzing the fishery as a non-cooperative game in an essentially static framework was used by Mesterton-Gibbons (1993) who focussed on multiple agents exploiting a national fishery and Ruseski (1998) and Quinn and Ruseski (2001) in their study of strategic interaction among countries in an international fishery.[8]

We adopt a partial equilibrium framework to focus on the fisheries sector. Markets are competitive. The price of fish is endogenous and determined by global supply and demand. There are 3 countries: Home, Foreign and the rest of the world (ROW). In most of what follows, we assume that Home and Foreign export fish and that ROW imports fish.[9] In section 6 we briefly consider other trade patterns.

We set up the model for the Home country; the analogous Foreign variables will be indicated with an asterisk (*). The (exogenous) opportunity cost of labour is w, and prices of all other goods and inputs (which are suppressed here) are treated as given. We represent consumer well-being with a quasi-linear indirect utility function U that takes the form

$$U = V(p) + I$$

where I is national income and p is the domestic price of fish. Alternatively one can think of V(p) as consumer surplus. From Roy's Identity, the domestic demand for fish is

$$D(p) = -V_p(p)$$

since the marginal utility of income is 1.

There is a continuum of potential fishers in each of Home and Foreign indexed by *i*. Each fisher has an endowment of 1 unit of labour per period. Two types of regulation are

[8] Static coalition games that are used to analyze international fishery agreements also focus on steady-state stocks levels (see for instance, Pintassilgo and Lindroos, 2008). Kronbak and Lindroos (2006) analyze, using steady state values in the objective functions, how the level of enforcement set by the authorities affects the way fishermen form coalitions.

[9] The three country approach follows that adopted by Brander and Spencer (1985) in their paper on strategic export subsidies. It was also used in Bagwell and Staiger (2001b) in their analysis of agricultural subsidy agreements.

available to government: (1) taxes or subsidies for fishers; and (2) regulations that increase the cost of fishing (here we are influenced by Homans and Wilen, 1997, and Grainger and Costello, 2015).

In practice, subsidies take many forms, most of which can be thought of as reducing costs. Since we use a stylized model with labour as the only primary input, we model subsidies as an amount *s* available for each active fisher per period of harvesting. Fishers have an outside option of employment at wage w, so the cost of fishing is the fisher's opportunity cost of labour. The subsidy reduces this opportunity cost by providing a payment of s per unit of labour allocated to the fishery.[10] We allow *s* to be positive or negative; if $s < 0$, then it is a tax.[11]

We use a slightly generalized version of the Schaefer (1957) fisheries model.[12] The harvest (per period) for a typical fisher i is

$$h_i = \alpha(R) X L_i \tag{1}$$

where *X* is the stock of fish (harvesting productivity is increasing in the stock), L_i is labour supply of fisher i, and R is an index of the intensity of regulations. We assume that regulation raises the cost of fishing. In practice, regulations involve rules such as restricting the length of the season, restrictions on the types of gear that can be used, restrictions on where and when fishing can take place, restrictions on the size of fish than can be caught, and so on. We do not focus on the details of each of these different types

[10] In a more general model, one could consider fuel subsidies, capital investment subsidies (for boats and other equipment), unemployment insurance subsidies, regional development programs that provide benefits to staying in fishing communities, and so on. All of these would have the effect of creating incentives for marginal fishers to enter (or not exit) the fishing sector (they are "effort-enhancing" subsidies). For simplicity, we model this with a direct subsidy targeting the fisher. Another broad class of subsidies enhances and protects fish stocks (fishery research, stock enhancement, management costs, etc.). We do not consider these types of subsidies as they were not the primary motivation behind the drive to reduce fisheries subsidies under the auspices of the WTO.

[11] One could alternatively consider subsidies that depend on harvest levels. These however are more difficult to monitor and implement. The results of the paper would not be significantly different.

[12] This is a standard model in the fisheries literature - see for example Clark (1976); it has also been used in the trade and fisheries literature (Brander and Taylor, 1997).

of regulations, but simply assume that they reduce productivity for a given level of the stock. We assume that $\alpha \in [0, \bar{\alpha}]$, with $\alpha(0) = \bar{\alpha}$, and with $\alpha' < 0$ *and* $\alpha'' > 0$. That is, more stringent regulation lowers productivity in fishing. We assume for simplicity that monitoring and implementing regulations is costless. This means that we can think of the regulator as choosing a level of α directly and so in what follows, we suppress R to economize on notation.

Because we assume that fishers are identical and each supply 1 unit of labour, then from (1), we have

$$h = \alpha X \tag{2}$$

where h is harvest per fisher. With N fishers active, aggregate harvest is

$$H = \alpha X N \tag{3}$$

The stock of fish is endogenous and depends on annual harvesting. We assume a logistic growth model for the fish stock:

$$\frac{dX}{dt} = rX\left(1 - \frac{X}{\bar{X}}\right) - H \tag{4}$$

where r > 0 is the intrinsic growth rate of the stock and $\bar{X}$ is the carrying capacity of the environment (the steady state stock in the absence of human intervention).

In steady state (dX/dt = 0), and so (3) and (4) imply that the fish stock is

$$X(N, \alpha) = \bar{X}\left[1 - \frac{\alpha}{r} N\right] \tag{5}$$

Note that the stock is extinguished for $N \geq r/\alpha$. We will assume that the government must choose policies such that in equilibrium $N < r/\alpha$ (that is, it cannot subsidize employment in a fishery that no longer exists). This is a constraint on government policy; we will focus on interior solutions where the employment motive is not sufficiently strong so that this constraint binds.[13]

[13] As we will see below in Figure 1, if there are no subsidies, the fishery will not be extinguished in a free entry equilibrium as long as w >0. A strong employment motive will generate subsidies;

Using (3) and (5), the steady state harvest is therefore

$$H(N,\alpha) = \alpha \bar{X}\left[1 - \frac{\alpha}{r}N\right]N \tag{6}$$

To determine the steady state number of fishers N, for given levels of the policy variables and price, recall that each potential fisher has 1 unit of labour with opportunity cost w, so the net return per period of fishing is

$$\pi(p, X, \alpha) = ph(X, \alpha) - w + s$$

where s is a subsidy (or tax if s < 0) available for each fisher per period of fishing.
As the labour is the only primary input, the subsidy could be also interpreted as a subsidy to employment. This equivalence would not hold in a more general setting with additional factors of production.

Fishers will enter as long as net returns are positive. Hence the marginal fisher N is determined by a zero profit condition ($\pi = 0$). Using (2), this can be written as

$$p\alpha X = w - s \tag{7}$$

Since $\alpha X = h = H / N$, this says that entry continues until the value of the average product of labour (pH/N) is equal to the wage less the subsidy. We illustrate the solution in Figure 1. The free entry condition (7) can be rewritten as

$$H(N,\alpha) = \frac{(w - s)}{p}N \tag{8}$$

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we assume that the employment motive is not sufficiently strong so that w-s ≤ 0. The analysis can easily be extended to the case of a stronger employment motive where the constraint binds, but it would add to the number of cases to be analyzed.

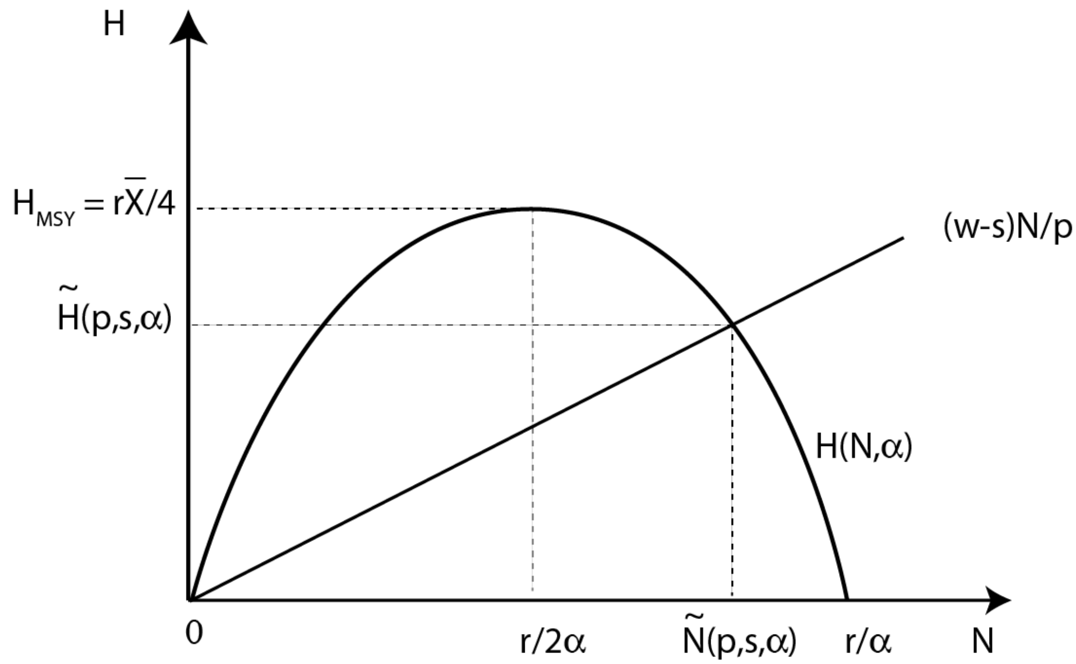

Figure 1. Free entry equilibrium determines H and N.

The left hand side of (8) is the sustainable harvest function (6). It is hump-shaped as illustrated. Given regulations (and hence given α), an increase in the number of fishers (N) initially leads to an increase in harvest. The harvest level peaks and then eventually declines to zero as N increases because of stock depletion. To find the peak choose N to maximize H in (6). This yields

$$N = \frac{r}{2\alpha} \qquad (9)$$

Substituting this into (6) yields

$$H_{MSY} = \frac{r\bar{X}}{4} \qquad (10)$$

The maximum sustainable harvest, which we have denoted H_{MSY}, is known in the fisheries literature as the "maximum sustainable yield" (MSY)[14]. As noted above the stock is totally wiped out if $N \geq r/\alpha$ on a sustained basis. This puts an upper bound on sustainable employment in the fishery for given α.

[14] See for example Clark (1976).

The right hand side of (8), (w-s)N/p, is the total real cost to the private sector of fishing. Given prices, this is an upward sloping straight line.[15]

The solution to (8) yields the harvest supply function $\tilde{H}(p,s,\alpha)$ and the employment function $\tilde{N}(p,s,\alpha)$. This is illustrated as the intersection of the two curves in Fig. 1.

Note that increases in the price of fish rotate the cost line downward. Starting with the price very low, an increase in price initially leads to increased harvest, but at some point further price increases lead to a decrease in harvest. That is, as is well known in the fisheries literature, long run harvest supply curves tend to be backward bending. This is because of stock depletion. High prices attract more fishing effort, which for given fish stock increases H, but in the long run depletes the stock, which lowers sustainable H. For $N > r/2\alpha$, the second effect dominates.

Increases in the subsidy also rotate the cost line downward. This reduces the opportunity cost of labour and increases employment (given p and α). Harvest levels may rise or fall depending on the degree of fish stock depletion.

More stringent regulations (a reduction in α) stretch the sustainable harvest curve $H(N,\alpha)$ to the right. This allows positive sustained harvest levels at higher levels of employment. Note, however, that more stringent regulations do not affect the magnitude of the maximum sustainable yield. H_{MSY} is independent of technology and is determined by the ecosystem and the biology of the fishery.

If there is no regulation and no subsidy, then the outcome is known as the *open access equilibrium*. At this point $N = \tilde{N}(p,0,\bar{\alpha})$. Employment levels lower than this [$N < \tilde{N}(p,0,\bar{\alpha})$] can be supported without subsidies. Our focus in this paper is on incentives to reduce subsidies, so we assume throughout that the weight on employment in the government's objective function is sufficiently high to generate subsidies to push

[15] Note that s < w to avoid extinguishing the stock.

employment above the open access level.

The price of fish is determined by global market clearing. The global demand for fish is given by $D^W(p)$, which is assumed to be decreasing in p. Let $\tilde{H}^*(p,s^*,\alpha^*)$ denote the foreign supply of fish where s* is the foreign subsidy and α* is foreign regulation ($\tilde{H}^*$ has properties analogous to $\tilde{H}$). Then the world price of fish is determined by

$$D^W(p) = \tilde{H}(p,s,\alpha) + \tilde{H}^*(p,s^*,\alpha^*) \tag{11}$$

We assume that

$$\tilde{H}^*_p + \tilde{H}_p - D^W_p > 0; \tag{12}$$

that is, we assume stability so that an outward shift in supply lowers prices and an inward shift raises prices.

It will sometimes be convenient to make use of the inverse demand curve corresponding to $D^W(p)$. We denote this $p^D(H + H^*)$. It gives the price that clears the market if total harvest is $H + H^*$.

Government objective

Governments use subsidies for a variety of reasons, but a reading of the literature on fisheries subsidies indicates that one of the main motivations for subsidies is to promote and maintain employment in the fishery sector (see for example Hilborn, 2007, and World Bank, 2009). In some cases this is driven by pressure to maintain the viability of communities dependent on the fishery, in others it reflects the role of the fishery as source of employment for the poor. We will therefore assume that the government weighs both social surplus and employment in the fisheries sector when choosing policy.

As noted above, we focus on steady states and assume that the government discount rate approaches zero. That is, the government is concerned with sustained surplus and employment in the fishery. In the absence of political pressure to maintain employment and if there were no terms of trade effects this would mean that the government would maximize sustained surplus from the fishery as in Brander and Taylor (1997).

Total surplus (or rent) generated by the Home fishery is given by

$$\Pi(p, N, \alpha) = pH(N, \alpha) - wN \tag{13}$$

Total private surplus accruing to fishers is $\Pi + sN$, but the revenue requirement to fund the subsidy is sN. We assume that the subsidy is financed via lump sum taxation from the rest of the economy so that the social return to the fishery net of subsidies or taxes is given by Π. The government is assumed to weigh both social surplus (the return to consumers and producers, and government net revenue) and employment in the fisheries sector when deciding on policy. For simplicity we will work with a simple quasi-linear objective function:

$$W = V(p) + \Pi(p, N, \alpha) + \lambda\varphi(N) \tag{14}$$

where φ is increasing and strictly concave in N, and λ is a parameter that captures the weight placed by the government on fisheries employment. Note that other components of national income have been suppressed because they are exogenous. Equation (14) can be thought of as the sum of consumer surplus, resource rents and the government's perception of the benefits of employment in the fishery.

Social return to the fishery net of subsidies or taxes is given by the function Π. It is worthwhile noting that the function φ does not represent the indirect utility of potential workers in the fishery, which could ultimately depend on wages and on other prices, which are exogenously given in our partial equilibrium setting. Function φ rather reflects the political benefits of the government from promoting and maintaining employment in the fisheries sector. These benefits could be related to have less contests and strikes from fishermen, and, in turn, to establish a "social peace" and obtain political support from agricultural and fishery lobbies. Hence, the parameter $\lambda \geq 0$ could be interpreted, as in Bagwell and Staiger (2001b), a political-economy parameter, with $\lambda > 0$, when political-economy considerations affect the government's choice of policy variables.

3. Subsidies with no other regulations in place

We begin by focusing on subsidies (or taxes) alone and assume that other regulations are exogenous (that is, in this section of the paper, we set $\alpha = \bar{\alpha}$). We think of this as a case where governments' resource management capacity is weak, so that fisheries may end up being seriously depleted. We focus on the Home government's problem; the Foreign government solves its own analogous problem. We consider a non-cooperative Nash equilibrium where each government chooses its subsidy, given the subsidy of the other government.

The Home government chooses the subsidy s to maximize its objective (14) subject to the steady state fish stock constraint (5) and the free entry condition (8), treating the foreign subsidy as given. We focus on interior solutions where the employment motive is not sufficiently strong that the fish stock would be extinguished.

Noting that we can write

$$H(N,\alpha) = \alpha X(N,\alpha)N,$$

the first order condition yields[16]

$$\left[p\alpha N X_N - s + \lambda\varphi'(N) \right] \frac{dN}{ds} + E\frac{dp}{ds} = 0 \tag{15}$$

where $E \equiv H - D$ is net exports of fish, with D denoting domestic demand for fish. Note in (15), dN/ds is the full effect of s on N, taking into account the effect of the subsidy s on the price of fish. That is, from (6) and (8) and as illustrated in Figure 1, we have $N = \tilde{N}(p,s,\alpha)$ and so

$$\frac{dN}{ds} = \tilde{N}_p \frac{dp}{ds} + \tilde{N}_s \tag{16}$$

where $\tilde{N}_s \equiv \partial \tilde{N} / \partial s$ and $\tilde{N}_p \equiv \partial \tilde{N} / \partial p$. As we see from Figure 1, $\tilde{N}_s > 0$; that is, the direct effect of the subsidy is to increase employment (as long as the fish stock is still positive). If this also increases fish harvests, then p will fall, which would dampen the

[16] The free entry condition (7) has been used in obtaining (15).

increase in N, but not reverse it if the market is stable. We will discuss this in more detail below when we analyze the sign of dp/ds.[17]

An increase in Home's subsidy has two effects on the government's welfare function: an employment effect (a change in N) and a terms of trade effect (a change in the value of exports). We can use (15) to solve for the government's optimal subsidy (given the foreign subsidy):

$$s = p\alpha NX_N + \lambda\varphi'(N) + E\frac{dp/ds}{dN/ds} \tag{17}$$

The expression for the subsidy has three terms, reflecting three different motives for policy intervention in the fishery.

First suppose that the price of fish was fixed (so that there was no terms of trade effect) and that there was no employment motive so that the government was maximizing social surplus. This would leave just the first term in (17) and we would have:

$$s = p\alpha NX_N < 0$$

In this case the optimal policy is a harvest tax that fully internalizes the harvest externality. This is a standard result from the fisheries literature. Harvesting by any one fisher leads to more sustained pressure on the fishery and this reduces the stock. This is an externality because the fall in the stock size reduces the productivity of all fishers. The social cost of this loss in productivity per entrant is $p\alpha NX_N$. The tax reflects the cost of the stock depletion caused by an additional entrant.

The second term in (17), (which is positive) reflects the benefits perceived by the government from increased employment in the fishery. This employment effect is valued by the term $\lambda\varphi'(N)$.

The final term in (17) is the terms of trade effect. Since we are assuming that Home

[17] See footnote 18.

exports fish, it has an incentive to manipulate the subsidy at the margin so that it leads to an increase in the price of fish. If a subsidy reduces the world price of fish, then this final term would be negative and the terms of trade motive would reinforce the case for a tax. However, as we show below, a subsidy in the fishery can in some cases improve the terms of trade.

The foreign government solves a similar problem and finds its optimal subsidy s* given Home's subsidy. This leads to a Nash equilibrium in subsidies. The equilibrium subsidies could be positive or negative. However if the employment motives are sufficiently strong (i.e. λ and λ^* sufficiently large) then they dominate the other effects and the governments will subsidize the fishery. We assume that this is the case in all of what follows (because we want to analyze the incentives to come to an agreement to reduce subsidies).

Terms of trade effects

A potential for international agreement arises when the behaviour of one country affects another. In this model this cross-country linkage occurs via terms of trade effects - the effects of changes in one country's subsidy on the world price of fish. We therefore need to analyze dp/ds.

Using (11), the effect of an increase in Home's subsidy on the world price of fish is given by

$$\frac{dp}{ds} = -\frac{\tilde{H}_s}{\tilde{H}_p^* + \tilde{H}_p - D_p^W} = \left[\frac{\alpha \bar{X}\left(\frac{2\alpha N}{r} - 1 \right)}{\tilde{H}_p^* + \tilde{H}_p - D_p^W} \right] \tilde{N}_s \tag{18}$$

As noted above when we discussed Figure 1, supply curves are backward bending in open access fisheries. Increasing the return to fishing encourages entry, and for given stock levels, this increases output. But increased harvesting also depletes the stock, and eventually the stock depletion effect dominates. Hence the effect of an increase in the subsidy on prices depends on how depleted the stock is. Referring to (18), if N is small (i.e. fishing effort is low so the stock is in good shape), then an increase in the subsidy will lower the price of fish because it increases supply. But if N is large, then an increase in the subsidy leads to a lower long run harvest level (because the stock depletion effect dominates) and hence the price rises.

To summarize,

$$\frac{dp}{ds} < 0 \quad if \quad N < r/2\alpha$$
$$\frac{dp}{ds} > 0 \quad if \quad N > r/2\alpha$$

This is one of the important ways that the global impacts of fishery subsidies differ from other types of production subsidies such as agricultural subsidies. Normally we expect production subsidies to worsen an exporting country's terms of trade because the subsidy increases output which leads to a fall in the world price. However, because of the stock depletion effect, a distinctive feature of fisheries subsidies is that they can improve a fish exporting country's terms of trade. In this case, referring to (17), the beneficial terms of trade effect reinforces the employment motive for increasing the subsidy.

The result that fisheries subsidies can improve the terms of trade requires that the country be operating in the region where its harvest supply function is downward sloping. To see when this may happen, refer to Figure 1. Given s, the equilibrium employment is $\tilde{N}(p,s,\alpha)$. At this point, the country is operating on the downward sloping part of its supply curve - an increase in p would rotate the cost line down, increase N, and reduce H. In the absence of a subsidy (s = 0), the equilibrium employment could be either to the left or the right of the point that generates the maximum sustainable harvest ($H_{MSY} = r/2\alpha$). If it is to the left of this point, the supply curve is upward sloping; if it is to the right it is downward sloping. The outcome depends on the harvesting productivity α (if α is low the fishery is more likely to be under-exploited and on the upward sloping part of its supply curve) as well as r and w. However, in all of these cases, note that if λ, the government's weight on employment, is sufficiently large, then the government will choose a subsidy that is sufficiently high that it pushes the fishery into the region where the supply curve is downward sloping.[18]

Spillover effects of Home's fishery subsidies on the rest of the world

Let us now consider the effects of Home's subsidy on the other fish-exporting country. The foreign government's objective function can be written as

$$W^*(p,s^*) = V^*(p) + \Pi^*(p, N^*, \alpha^*) + \lambda^* \varphi^*(N^*) \tag{19}$$

where $N^* = \tilde{N}^*(p, s^*, \alpha^*)$ is determined by the foreign free entry condition (the Foreign version of (8)) and we are treating regulations and hence α^* as given in this section. W* does not depend directly on Home's subsidy *s*, but does so indirectly via the effect of Home's subsidy on the price of fish. Hence the effect of an increase in Home's subsidy on Foreign is:

$$\frac{dW^*}{ds} = W_p^* \frac{dp}{ds} = E^* \Psi^* \frac{dp}{ds} \tag{20}$$

where E^* is foreign net exports of fish and

$$\Psi^* \equiv \left[\frac{\tilde{N}_{s^*}^*}{\tilde{N}_{s^*}^* + \tilde{N}_p^* p_{s^*}} \right] > 0 \tag{21}$$

and where we have used the Foreign government's first order condition for the choice of s* to derive Ψ^*.[19]

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[18] At this point we can verify the claim that dN/ds > 0 as discussed after equation (16). Let $\Delta \equiv \tilde{H}_p^* + \tilde{H}_p - D_p^W$. Then (18) can be written as $dp/ds = -H_N \tilde{N}_s / \Delta$. Using this in (16) and noting $\tilde{H}_p = H_N \tilde{N}_p$, we have $dN/ds = \left[1 - \tilde{H}_p/\Delta\right]\tilde{N}_s$. But $1 - \tilde{H}_p/\Delta = \left(\tilde{H}_p^* - D_p^w\right)/\Delta > 0$ and also $\tilde{N}_s > 0$ and so dN/ds > 0 as claimed.

[19] The Foreign government's first order condition for s* is $W_p^* p_{s*} + W_{s*}^* = 0$. Use (19) to find W_p^*

Condition (20) says that the effect of Home's subsidy on the foreign government depends on the sign of the terms of trade effect. Since Foreign exports fish, then foreign terms of trade improve if p rises and deteriorate if p falls. And as we saw above, Home's subsidy causes the price to fall if its supply curve is upward sloping, but can cause it to rise if the employment motive is strong. That is, one country's subsidy may either benefit or harm the other exporting country depending on the strength of the employment motive.

If the employment motive in both countries is relatively weak, and if technology or other factors mean that the fishery is relatively underexploited, then we expect both countries to be operating in the region where their harvest supply curves are upward sloping. This is a case where the fish stocks in both countries are healthy and where the global spillover effects of subsidies are similar to the case of agricultural subsidies. Home's subsidy pushes down the world price and this undermines Foreign's attempts to support its own fishers. Foreign's subsidy has a similar effect on Home and so the countries find themselves in a Prisoner's Dilemma. In the non-cooperative equilibrium there will be excessive subsidization of the fisheries. There is an incentive for the two exporting countries to negotiate an international agreement to reduce subsidies; such an agreement would both reduce financing costs of the subsidies and allow some recovery of the fish stocks.

If instead the employment motive in both countries is sufficiently strong, then both will be on the downward sloping part of their harvest supply curves. In this case each country's subsidy reduces the world supply of fish and hence improves the terms of trade of the rival exporting country. There is no incentive for the exporting countries to get together to work out a deal to reduce their subsidies - each government would be worse off from such a deal. Instead, cooperation among the exporting countries would lead to higher subsidies. To confirm this, consider the effect of a change in Home's subsidy s on the joint return (W+W*) to the governments of the two exporting countries:

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and W^*_{s*}. This can be used to show $W^*_p = E^* + W^*_{s*}\tilde{N}^*_p / \tilde{N}^*_{s*}$. Using the first order condition to eliminate W^*_{s*} yields (20). The positive sign of Ψ^* in (21) follows because market stability implies $\tilde{N}^*_{s*} + \tilde{N}^*_p p_{s*} > 0$ using the same argument as in footnote 16.

$$\frac{d(W+W^*)}{ds} = W_s + W_p \frac{dp}{ds} + W_p^* \frac{dp}{ds} \tag{22}$$

At the non-cooperative equilibrium Home sets the sum of the first two terms equal to zero and ignores the final term, which is the effect of the subsidy on the foreign country. Hence if we evaluate at the non-cooperative equilibrium, we have:

$$\left.\frac{d(W+W^*)}{ds}\right|_{dW/ds=0} = W_p^* \frac{dp}{ds} > 0 \quad if \qquad \frac{dp}{ds} > 0 \tag{23}$$

When countries are in the region where the harvest supply curve slopes down, then starting at the non-cooperative outcome, a cooperative agreement that increased subsidies in both countries would benefit each.

To summarize, we have:

Proposition 1. There exist $\underline{\lambda}$ and $\underline{\lambda}^*$ such that if $\lambda > \underline{\lambda}$ and $\lambda^* > \underline{\lambda}^*$ (that is, if each government puts a sufficiently high weight on employment in their fishery), then
(i) Home and Foreign subsidize their fisheries
(ii) increases in either country's subsidy leads to a fall in long run fish stocks and an increase in the price of fish
(iii) Home and Foreign governments would not gain from an agreement to jointly reduce their subsidies.//

We therefore obtain the paradoxical result that an international agreement among exporting countries to reduce subsidies can be particularly difficult in the case where fisheries are heavily exploited. A joint reduction in subsidies would be good for fish stocks, and it would improve economic efficiency, but it would not be in the interests of politically-motivated governments when they face strong employment pressures.[20]

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[20] There may also be asymmetries among fish-exporting countries. Suppose Foreign has a strong employment motive and is on the downward sloping part of its harvest supply curve, and Home has a weak employment motive and is on the upward sloping part of its supply curve. Foreign would gain if Home reduced its subsidy (since fish prices would rise as Home harvests fell), but Home would lose if Foreign reduced its subsidy (since Foreign stocks would recover and fish prices would fall). The spillover effects go in opposite directions. So there would not be a

There is still, however, some scope for international agreements because of the spillover effects of the subsidies into fish importing countries. In the case where fisheries are seriously depleted, subsidies lead to reductions in long run harvest and hence higher long run fish prices, which harms importers. Thus importing countries have an incentive to offer Home and Foreign some concessions to reduce subsidies. This would require that the negotiations on fisheries be imbedded in a larger negotiation in which importing countries offer concessions in other sectors in return for a commitment to reduce fish subsidies. But this highlights again why negotiations on fish subsidies differ somewhat from subsidies in other contexts. Typically subsidies lower prices and benefit consuming countries and so the main driver of an agreement would be to curtail the Prisoner's Dilemma among exporters. In the case of fisheries, the Prisoner's Dilemma aspect may not be operative, and so concessions from importing countries would have to lie at the foundation of a potential deal.[21]

4. Two Instruments: Subsidies and Regulations in Fisheries with High Depletion Potential

Up to this point, we have analyzed the case where governments have just one instrument available - a harvest tax or subsidy. That is, we have held other regulations and hence α constant. We can think of that analysis as applying to countries with little capacity to enforce effective fishery regulations. In practice, however, most governments have available a set of regulations that are used in conjunction with subsidies, and many governments are able to engage in effective resource management. Our objective in this section is to show that even when fisheries are effectively managed (and therefore not seriously depleted), subsidies can persist and there may be little or no incentive to negotiate agreements to reduce these subsidies.

We proceed by first finding the non-cooperative equilibrium when the two instruments

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consensus among fish exporters in favor of an agreement to reduce subsidies.

[21] Section 4 considers how the exporting countries may respond to a commitment to reduce subsidies in a way that potentially would undermine any such agreement.

are available and then ask whether there is potential for an agreement that constrains the use of subsidies when governments are free to adjust their fishery regulations unilaterally. While in principle, one could imagine international agreements that constrain both fishery regulations and subsidies, this would go well beyond the scope of trade agreements as it would require international constraints on domestic conservation policy.

The government's objective (14) can be written as

$$W = V(p) + pH + \lambda\varphi(N) - wN \tag{24}$$

The first two terms capture the consumption and revenue benefits from harvesting fish; the remaining two terms measure the political benefits of employment in the fishery less the opportunity cost of labour. As before we focus on interior solutions where the employment motive is sufficiently strong to induce a subsidy.

It is useful to introduce the following definition.

Definition: A fishery has ***high depletion potential*** if

$$N^{\lambda} > \frac{r}{2\bar{\alpha}} \tag{25}$$

where

$$\lambda\varphi'(N^{\lambda}) = w \tag{26}$$

A fishery with high depletion potential is one where the government's employment motive is strong enough to push employment to a level that would reduce the stock below the level that supports the maximum sustainable yield if the fishery were unregulated. The condition (26) determines the employment N^{λ} that sets the marginal political benefit of extra employment in the fishery (ignoring the effects on the harvest rate) equal to its marginal social cost (given by the wage). And $r/2\bar{\alpha}$ in (25) is the employment that supports the maximum sustainable yield from the fishery when it is unregulated (recall Figure 1). Fisheries are more likely to have high depletion potential if the employment motive is high (high λ), if the intrinsic growth rate r of the fish stock is low, if the harvesting technology is very productive (high $\bar{\alpha}$), or if the opportunity cost of labour w is low. Finally note that fisheries with high depletion *potential* need not actually be depleted because regulations can be tightened up to reduce α and protect fish stocks even at high levels of employment.

In this section we focus on fisheries with high depletion potential in both Home and Foreign. This is the most interesting case, both because the fisheries are potentially vulnerable because of strong employment pressure, and because the incentives to reduce subsidies are very different than for other goods (such as for agricultural products). Section 5 briefly considers fisheries with low depletion potential.[22,23]

The key issue that differentiates the results of this section from those of Section 3 is that when both subsidies and regulations are available in a fishery with high depletion potential, it is possible to independently target both the employment level and the domestic harvest rate. In section 3, part of the cost of using a subsidy to promote employment is that it leads to stock depletion. In this section, given any desired employment level supported by subsidies, the fish stock can be protected by tightening fishing regulations. This allows the government to choose regulations and subsidies to support any feasible level of sustained harvesting and any desired employment level greater than or equal to that required to support the harvest target.

Because governments ultimately care about H and N, it is convenient (and makes the analysis more transparent) to consider a non-cooperative game between the two exporters where H and N are the strategic variables. Each government simultaneously chooses sustainable harvest rates (H) and employment (N) treating the other government's harvest and employment targets as given. They then implement their targets with their available

[22] We treat the two cases separately because when there is high depletion potential the government will want to use both instruments, but when there is low depletion potential there is little or no need to use regulations because the fish stock is not threatened even when there are subsidies. Hence when there is low depletion potential we are (except when market power is very strong) back in the case where there is effectively only one instrument.

[23] We could also consider high depletion potential in one country and low depletion potential in the other, but we do not pursue this to avoid making the paper unduly long. The novel insights come from the high depletion potential case.

policy instruments.

To see that this is feasible, let $p^D(H+H^*)$ denote the inverse global demand for fish.[24] Then (given H*) if Home wants to implement some H and N, the required subsidy is given by the free entry condition (8) which implies

$$s = w - \frac{p^D(H+H^*)H}{N} \tag{27}$$

The required α is determined by the sustainable harvest function (6). Note that because equation (6) implies that H is a hump-shaped function of α (given N), then in general α is not unique. Given N, a given (feasible) harvest rate can typically be supported by either strong regulations (a low α) which corresponds to a large fish stock, or weak regulations (a high α) which corresponds to a more depleted fish stock.

Finally, a key issue that drives much of the following analysis is that the maximum sustainable harvest is capped by ecological constraints. As we discussed earlier in when describing Figure 1, sustainable harvest is constrained by the reproductive capacity of the fish stock. We denoted the maximum sustainable yield by H_{MSY}. Given a target employment level N, the government could implement H_{MSY} (if it turns out to be optimal) with appropriate choice of regulations. That is, using (9), the harvest level will be H_{MSY} if:[25]

$$\alpha = \frac{r}{2N} \tag{28}$$

We are now ready to solve the Home government's problem. Given H* and N*, it chooses H and N to maximize (24) subject to $H \le H_{MSY}$.

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[24] That is, this is the inverse demand corresponding to the demand function $D^W(p)$ previously defined.

[25] Recall that there is an upper bound on harvesting productivity: $\alpha \le \bar{\alpha}$. Hence H_{MSY} cannot be implemented via (28) with arbitrarily low N. However if the fishery has strong depletion potential then the employment level desired by the government will always be sufficiently high to support any $H \in [0, H_{MSY}]$.

Proposition 2. Suppose the fishery has strong depletion potential and governments can use both regulations and subsidies to support their desired targets for Harvests (H) and employment in the fishery (N). Then if there is a sufficiently high weight on employment, Home's best response to Foreign H* and N* is given by

$$\lambda\varphi'(N) = w \tag{29}$$

and

$$H = H_{MSY} \qquad if \;\; p^D(H + H^*) + Ep^D_H(H + H^*) > 0 \text{ at this level of H;} \tag{30}$$

$$p^D(H + H^*) + Ep^D_H(H + H^*) = 0, \qquad \text{otherwise} \tag{31}$$

where E is home exports.
Analogous conditions apply to Foreign.
Proof: see Appendix.

To interpret this solution, note that the government cares about two things: employment in the fishery and the benefits of fish harvesting (consumption and export of fish). With two instruments, the government is able to target both of these directly.[26] Equation (29) simply says that employment is chosen so that the marginal benefit of extra employment in the fishery (as perceived by the government) is set equal to its marginal social cost (given by the wage).

Given this level of employment, equations (30) and (31) determine the optimal harvest level. There are two possibilities, depending on the magnitude of the potential harvest relative to market power. If market power is not too strong, (i.e. if p^D_H is low) then the government wants to harvest as many fish as possible (on a sustained basis) and so sets H at the MSY level as indicated by equation (30). This amounts to choosing α to maximize

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[26] The solution is of course second best because of the restriction on the set of available instruments. If individual harvest quotas were available, then they could be employed instead of regulations that reduce productivity.

sustainable harvest given that the number of fishers is N. The solution to this problem is in (28). But if market power is strong (and the potential sustainable harvest level sufficiently high), then the government may want to produce less than the maximum sustainable harvest in order to push up the price and extract rent from foreign consumers. The optimal harvest in this case is determined by (31).

One striking aspect of these results is that the model predicts that (unless maximum sustainable harvest is sufficiently high and market power in the export market is sufficiently strong), the government will end up choosing a stock level that maximizes the sustained yield from the fishery. This is a policy often advocated by biologists and fishery managers but which has been criticized by economists as being inconsistent with economic efficiency.

Incentives for exporters to negotiate an agreement to reduce subsidies

We now consider the feasibility of a subsidy agreement. In this case fisheries are not excessively depleted because effective regulation is available, and so one might ask why there would be any pressure at all to reduce subsidies. It is true that the conservation motive for reducing subsidies is mitigated by the presence of effective regulation. However the usual trade-based motives that have lead the WTO to discourage subsidies in other sectors still apply. Subsidies support harvesting at a level higher than the first best,[27] and labour markets are distorted as governments are supporting higher levels of employment in the fishery than would minimize the cost of supporting equilibrium harvest levels.

To assess the feasibility of a subsidy agreement, consider the conditions for the joint optimum for the two exporting countries. It is sufficient to find the conditions that maximize W+W*.[28]

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[27] The MSY level of harvesting is rarely socially efficient, and in our model with a discount rate approaching zero, the efficient level of harvesting is less than the MSY level. This can be seen in Figure 1 where the surplus-maximizing level of N is to the left of the level of N that generates H_{MSY}.

[28] This follows (if lump sum transfers are available) because we have quasi-linear utility.

Proposition 3. Assume that the weight on employment is sufficiently strong that both countries want to use subsidies in the joint optimum and that fisheries in both Home and Foreign have strong depletion potential. The first order conditions for Home's policy in the joint optimum are:

$$\lambda\varphi'(N) = w \tag{32}$$

Regulations are chosen so that

$$\alpha = \frac{r}{2N} \qquad \textit{if} \;\; p^D + \left(E + E^*\right) p_H^D > 0 \text{ at this level of } \alpha; \tag{33}$$

$$p^D + \left(E + E^*\right) p_H^D = 0, \qquad \text{otherwise} \tag{34}$$

The subsidy s is then set as in (27) to implement the level of N implied by (32). Analogous conditions apply to the Foreign country.

Proof: see appendix.

Comparing Propositions 2 and 3, we see that as long as joint market power is not too strong (that is, if (33) holds), then employment and harvest levels are the same as in the cooperative and non-cooperative equilibria. In this case there is no incentive for an agreement to reduce subsidies. Only if market power is sufficiently strong relative to potential harvesting capacity - when (34) holds - will the cooperative and non-cooperative outcomes differ.

Let us now consider the intuition. If condition (33) holds, the joint optimum is the same as the non-cooperative equilibrium. It is jointly optimal for the exporting countries to choose regulations that maximize the sustained yield from the fishery and support employment levels that are consistent with (29) and its foreign analogue. Normally when two countries have power in an export market, we expect that they will have incentives to get together to reduce output and push up the price. The fishery case differs because sustained output is capped by the ecological constraint. When (33) holds, the joint marginal benefit of producing more fish at the non-cooperative outcome (taking into account both domestic consumption benefits and export revenue) is positive and hence there is no incentive to curtail output. Instead at the cooperative and non-cooperative equilibria, all countries would gain if more fish were produced.[29] But since we are at the maximum sustained yield point, long run harvests are as high as possible.[30] Subsidies still matter in that they are pushing employment above the socially efficient level and this is supported by regulations that reduce productivity in the fishery. But there are no spillover effects across countries. So there is no potential for an agreement to reduce subsidies.

If (34) holds, then the cooperative and non-cooperative solutions differ. In this case it is jointly optimal to reduce harvests below the MSY level to push up the price of fish. When the MSY constraint does not bind in the cooperative solution,[31] the cooperative and non-cooperative outcomes differ for the usual reason - each country internalizes the terms of trade effects for its own welfare, but neglects the effect on the other exporter. Hence there is a collective incentive to reduce harvests below the non-cooperative level.

However implementation of the cooperative solution (32) and (34) requires that *both* subsidies and fishery regulations be constrained. An agreement to reduce subsidies alone does not target harvest levels directly because it would leave countries free to adjust their fishery regulations unilaterally. If countries respond to a commitment to reduce subsidies by weakening their fishery regulations, then a subsidy agreement may not be effective in reducing harvests. To determine whether there is potential for a subsidy agreement, we therefore need to analyze how the choice of fishery regulations responds to a commitment to reduce subsidies below the non-cooperative level.

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[29] Notice that this means countries would like to produce more than the first best level of fish. This is because the employment motive essentially pushes the opportunity cost of harvesting to zero because employment is determined by (32) regardless of the harvest level.

[30] In other words, they are at a corner solution in the non-cooperative outcome and this prevents non-cooperative dissipation of their market power (as long as (33) holds).

[31] Note that there are cases where the MSY constraint binds in the non-cooperative outcome, but not in the cooperative solution. That is, although countries are at the MSY level in the non-cooperative outcome, they would jointly gain by reducing harvests. We discuss this case below.

Will a commitment to reduce subsidies affect harvest rates?

When there is a subsidy agreement, policy is determined in stages. In the first stage, the two fish-producing countries agree on subsidies, s and s*. In the second stage they are free to adjust their fishery regulations.

We focus here on the second stage. It is convenient to think of each country as choosing its harvest level at this stage, and then (given the subsidies) implementing it with an appropriate choice of regulations. That is, we consider the second stage of the game as a non-cooperative game in aggregate harvests subject to exogenous subsidies.[32] To see how this can be done, note that the free entry condition (8) implies

$$N = \frac{p^D(H+H^*)H}{w-s} \equiv N(H;\, H^*, s) \tag{35}$$

where recall that $p^D(H+H^*)$ is inverse global demand for fish. Thus given H* and s, N is determined by H. And referring to (6), once the government chooses H, it can be implemented by an appropriate choice of α, provided H is feasible (i.e. less than or equal to the MSY level).

Home's objective is given by (24). The first order condition for the choice of H can be written as

$$p^D + p_H^D E = -\left[\lambda\varphi'(N) - w\right] N_H \tag{36}$$

The left hand side is the marginal benefit of increasing H; the right hand side can be thought of as the marginal cost of increasing H via the impact of a change in H on employment via (35).

We illustrate the solution to (36) in Figures 2 and 3. Note that Home's choice of H depends on H*; we have illustrated the case where H* is at the non-cooperative level. This will allow us to analyze how a change in the subsidy changes Home's best response

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[32] Note that because there is now only one available policy instrument, H and N cannot be targeted separately. As we show below, once H is chosen, that determines N.

function for H in the neighbourhood of the non-cooperative equilibrium.

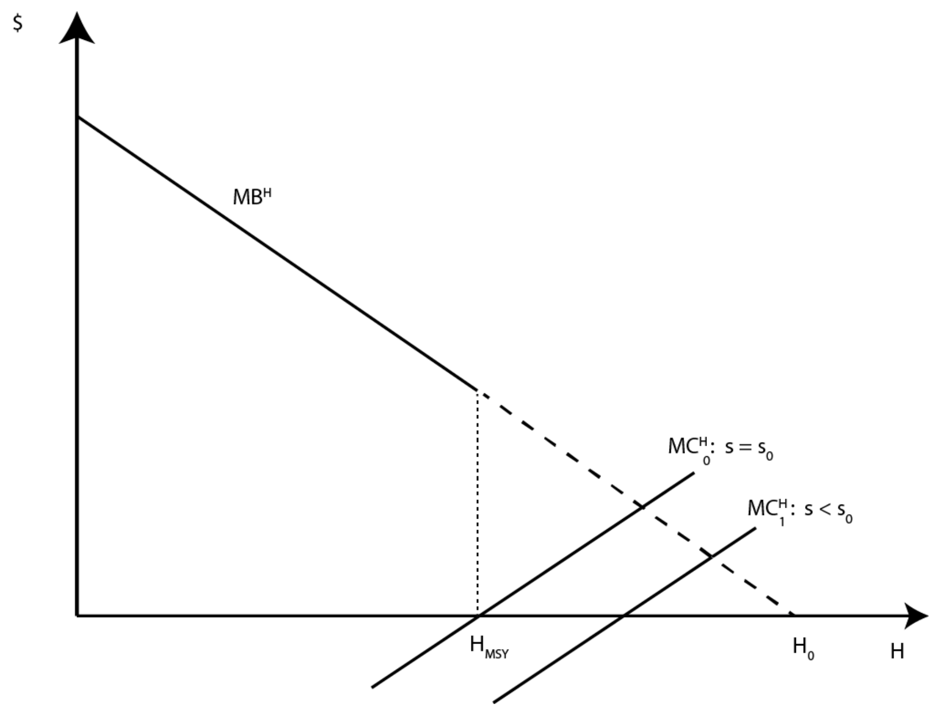

Figure 2. Effect of a change in subsidy when MSY constraint binds

Effects of subsidy agreement when MSY constraint binds in non-cooperative equilibrium

As we would expect from Proposition 2, there are two possibilities, depending on whether the MSY constraint binds. Figure 2 illustrates the case where it binds [i.e. Home's solution in the non-cooperative equilibrium is given by (29) and (30)].

The curve MB^H (the left side of (36)) slopes down. It intersects the H axis at H_0. However, given the ecological constraints, the maximum sustainable harvest is H_{MSY}. In Figure 2, $H_{MSY} < H_0$ so H_0 is not feasible and the feasible MB^H curve becomes vertical at H_{MSY}.

The curve MC^H sketches the right hand side of (36) and is the marginal cost (from the perspective of the government) of adjusting H if the subsidy is fixed.[33] Adjusting H is

[33] Although H above MSY is not feasible, for clarity we have sketched the marginal cost of increasing harvesting for H above the MSY level - we can still ask in principle how a hypothetical increase in H (if feasible) would affect the employment benefits.

costly because via (35), it affects employment. Two MC^H curves have been illustrated in Fig. 2. MC_0^H is the curve when the subsidy is fixed at the non-cooperative level; MC_1^H corresponds to a case where the subsidy has been reduced below that level. If we fix the subsidy at the initial (non-cooperative) level, then MC^H is upward sloping and goes through H_{MSY}. It goes through H_{MSY} because (29) holds when the subsidy is at the non-cooperative level. To see it slopes upward (at least in the neighbourhood of H_0), note that

$$\frac{\partial MC^H}{\partial H} = -\lambda\left(N_H\right)^2 \varphi'' - \left[\lambda\varphi' - w\right] N_{HH}. \tag{37}$$

The sign in (37) is clearly positive in the neighbourhood of H_0 because (29) holds and $\varphi'' < 0$.

We now want to determine how a reduction in the subsidy affects the optimal harvest level H. The MB^H curve is unaffected (given H*). How does a reduction in the subsidy affect the MC^H curve when the MSY constraint binds? It turns out that MC^H may shift either up or down, but in both cases small changes in the subsidy have no effect on H because MB^H is vertical. This is our main point: a commitment to reduce the subsidy may have no effect on harvest rates because governments will respond by manipulating harvest regulations.[34]

Using the right hand side of (36), the effect of a *fall* in the subsidy on the MC^H curve is given by

$$-\frac{\partial MC^H}{\partial s}\bigg|_{H=H_0} = \underset{(?)}{\lambda} \underset{(+)}{N_H} \underset{(-)}{N_s\varphi''} \tag{38}$$

[34] Here we are assuming that the constraint $\alpha \leq \bar{\alpha}$ does not bind so that the government is able to maintain a target harvest level with a lower level of employment. That is, the assumption is that the government has some room to weaken regulations without completely eliminating them. Our assumption that the fishery has high depletion potential ensures that the constraint does not bind for small changes in the subsidy. A sufficiently high employment motive would also ensure that the constraint does not bind even for large changes in the subsidy.

The sign is determined by N_H; that is, by whether or not an increase in H raises or lowers employment. From (35), the impact effect of a fall in the subsidy is to reduce employment at the initial level of H (that is, $N_s > 0$). From the government's perspective, employment is now too low and the issue is whether a change in harvest rates (via a weakening of regulations) would raise employment. Referring again to (35), note that the numerator is total domestic revenue from the fishery. Hence employment can be increased via a change in H if total revenue rises as H changes.

There are three possibilities. If an increase in H raises total revenue (demand is locally elastic), then that would mean a marginal increase in H would be beneficial via its employment effect ($N_H > 0$). Hence the reduction in the subsidy causes MC^H to shift *down*: at the initial level of H, $MC^H < 0$, because an increase in H is beneficial from an employment perspective.

If instead H has been chosen so that initially total revenue is maximized, then it is not possible to affect employment by changing H (i.e. $N_H = 0$), and so the MC^H curve will continue to intersect the H axis at the same point as it did initially.

And finally, if an increase in H *reduces* total revenue (demand is locally inelastic), then a marginal decrease in H would raise employment (i.e. $N_H < 0$) and so MC^H shifts *up*. Of course in all three cases, the choice of H depends on the intersection of the new MC^H curve with the MB^H curve.

When (30) holds (that is, when the MSY constraint binds) then any of the three possibilities above could arise.[35] The effect of a change in H on total revenue is

$$\frac{d[p^D(H+H^*)H]}{dH} = p^D + p^D_H H \tag{39}$$

And when (30) holds we have

[35] Note that when the MSY constraint binds, it is not feasible to increase H. But we can still ask hypothetically what would happen to employment if we could increase H.

$$p^D + p_H^D H > p_H^D D \tag{40}$$

since E = H - D where D is domestic consumption. If all fish are exported, then D = 0 and so (39) is positive. Total revenue rises if H rises. But if D > 0 and H is sufficiently large then (39) could be negative.

Figure 2 illustrates the case where a reduction in the subsidy causes the MC^H curve to shift down (that is total revenue rises if H were to rise). In response to the reduction in the subsidy the home government would like to raise H both because the marginal benefit of harvesting is positive and because it would increase employment benefits. But H is capped at the MSY level. So in response to the reduction in the subsidy, the government adjusts regulations to keep harvesting at the MSY level. That is, an agreement to reduce subsidies would be have no effect on harvest levels and hence no effect on the price of fish. There are no international spillover benefits because H does not change. And governments are worse off because employment falls. Hence there is no incentive for exporters to come to an agreement to reduce subsidies.

If instead the reduction in subsidies caused the MC^H curve to shift up, then for a discrete range of subsidy reductions, harvest levels would be unaffected because the MSY constraint binds. Only a very large discrete reduction in subsidies would lead to a fall in harvest and a positive spillover effect for the other exporter via the price increase.

We have already seen that when (33) holds there is no incentive for a subsidy agreement because the cooperative and non-cooperative solutions coincide. However, there are cases where it would be mutually beneficial for the two exporters to reduce harvests, but where the adjustment in regulations described above will prevent this from becoming feasible. This arises when (30) and (34) both hold. In the non-cooperative solution, the MSY constraint binds on both countries so their MB^H curves are vertical. But in the cooperative solution it would pay to reduce harvests below MSY levels to push up the price. Harvests in the non-cooperative case are too high because neither country internalizes the terms of trade effects of its actions on its trading partner.

In this case (because the MB^H curve is vertical) small reductions in subsidies are fully offset by weak regulations and do not lead to reductions in harvest levels. If exports are large relative to domestic consumption, even a large reduction in subsidies will not affect harvest levels (because the MC^H curve shifts down). There are no spillover benefits from a reduction in subsidies since H does not change (and so the price of fish does not change) and governments are worse off because employment falls. Hence although exporters would benefit from a reduction in harvest levels, a reduction in subsidies will not accomplish this and so an agreement to reduce subsidies would be opposed.

As discussed earlier, if exports are small relative to domestic consumption, a large reduction in the subsidy could push up the MC^H curve to a level that would lead to a fall in harvests. But the two exporting governments may not have any incentive to do this. With a subsidy reduction high enough to reduce H, there would be a discrete drop in employment benefits and only a marginal increase in benefits due to the terms of trade effects (higher fish price).

Effects of subsidy agreement when MSY constraint does not bind in non-cooperative equilibrium

There are of course cases where there is potential for an agreement among exporters to reduce subsidies. In our analysis of the two-instrument model above, the key factor that makes things different from a standard model of competing exporters is that there is a hard cap on sustainable output arising from the ecological constraint. If fish are sufficiently abundant (that is, if the MSY harvest level is sufficiently high), then the cap will not bind and the potential for a subsidy agreement would then be much like that for other commodities such as agricultural goods. Countries would produce excessively in the non-cooperative equilibrium because they do not internalize terms of trade effects for other exporters. And an agreement to reduce subsidies can be effective in reducing harvest levels.

We illustrate this case below. Now the MSY constraint does not bind so that (31) holds in the noncooperative equilibrium. We sketch condition (36) for this case in Figure 3.

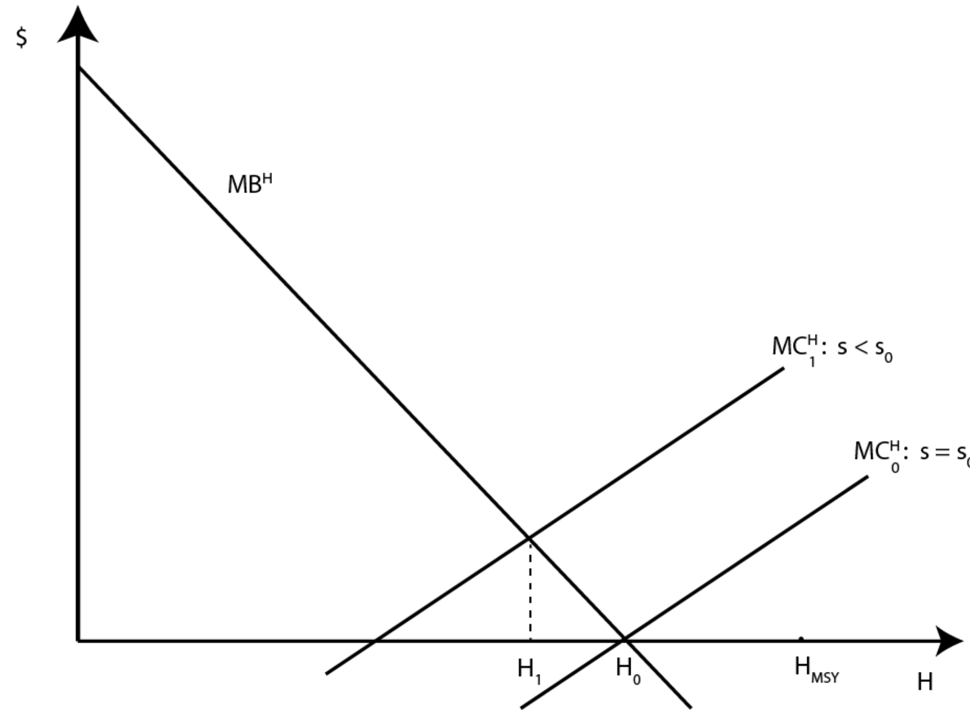

Figure 3. Strong Market Power: Exogenous reduction in the subsidy reduces H

As before the curves depend on H*; we have sketched them for the case where H* is at the non-cooperative level. Prior to an exogenous reduction in subsidies (that is, in the non-cooperative equilibrium), Home's solution was at H_o, where the marginal benefit of increasing H is set equal to zero. As discussed earlier, the MC_H curve also goes through this point. Note also that in this case, $H_o < H_{MSY}$ because the MSY constraint is not binding.

Now consider a reduction in Home's subsidy, treating H* as given. This has no effect on the marginal benefit of harvesting, but causes an upward shift in the marginal cost. To see why, recall our discussion of (38). The impact effect of the fall in the subsidy is to reduce employment below the government's target level. The government can increase employment by adjusting regulations to change the harvest level. Employment will rise only if aggregate revenue from harvesting rises (recall (35)). The change in revenue from a change in harvest is given by (39). And when (31) holds we have

$$p^D + p^D_H H = p^D_H D < 0$$

since E = H - D where recall that D is domestic consumption. This means that a reduction in harvest will be needed to increase employment and so the MC_H shifts up as we have illustrated in Fig. 3. Given H*, a reduction in subsidies causes H to fall; that is, Home's best response curve for H shifts in. We conclude therefore that an exogenous reduction in Home's subsidy reduces H, which increases the price of fish. Consequently there is a positive spillover effect across countries. Therefore when there is sufficiently strong market power and fish are sufficiently abundant, there is an incentive for the two exporting countries to negotiate an agreement to reduce subsidies.

To summarize, we have

Proposition 4. Suppose governments can choose both regulations and subsidies. If governments put a sufficiently high weight on employment in the fishery and if fisheries in both Home and Foreign have strong depletion potential, then there are three possibilities:
(i) The MSY constraint binds on the joint optimum; that is, (33) and (32) and their foreign analogue hold. In this case the harvest levels that maximize the joint welfare of the Home and Foreign country are the maximum sustained yield points and the non-cooperative equilibrium yields the same outcome as the joint optimum. An agreement to reduce subsidies would not benefit Home, Foreign, or ROW.
(ii) The MSY constraints bind at the country level in the non-cooperative equilibrium but not in the cooperative equilibrium. That is (34), (30) and (29) and the foreign analogues hold. In this case, there is an incentive for exporters to come to an agreement to reduce harvests, but small (and in some cases large) reductions in subsidies will not accomplish this - governments respond to a reduction in subsidies by loosening fishery regulation to keep harvest at the maximum sustainable level. In such cases, an agreement to reduce subsidies harms exporters.
(iii) Market power is strong both jointly and at individual country levels. That is (31) and (34) both hold. In this case, each government has an incentive to keep harvests below the MSY level in the non-cooperative equilibrium. There is an incentive to come to an agreement to reduce harvests, and a reduction in subsidies will accomplish this. Importing countries will be harmed.

Hence when governments use both subsidies and regulations to regulate the fishery, there is little scope for exporting countries to seek or support a subsidy agreement unless fish are sufficiently abundant - either because the non-cooperative outcome is jointly optimal or because an attempt to reduce harvests by reducing subsidies would be undermined by adjustments to domestic fishery regulations.

This analysis is also useful in thinking about how fish exporting countries would respond to a commitment to reduce subsidies that is tied to a larger trade agreement. Although exporting countries may not see benefits from mutual subsidy reductions, they might nevertheless be persuaded to accept constraints on subsidies in return for other concessions, such as increased market access in other industries. Given that there appears to be a large consensus among conservationists and many in the trade policy community that subsidies should to be reduced, this is a not unrealistic scenario. Our analysis suggests that these sorts of agreements may have limited success. Subsidy reduction agreements are likely to induce adjustments in regulations that maintain harvest levels. When the MSY constraint binds, governments will fully offset a reduction in subsidies by relaxing fishery regulations. This will maintain harvest levels, but employment in the fishery will be reduced. That is, an externally imposed subsidy agreement may have little effect on harvest levels or the fish stock.[36]

5. Subsidies and Regulations in Fisheries with Low Depletion Potential

In Section 4, we considered fisheries with high depletion potential. The availability of fishery regulations played a critical role because they can prevent stock depletion and (when combined with subsidies) support both high harvest levels and high levels of employment. Moreover, because regulations are used in the non-cooperative equilibrium, an agreement that reduces subsidies but does not constrain regulations means that

[36] Although harvest levels are not affected, an externally-imposed constraint on subsidies could succeed in reallocating labour away from the fishery. This labour reallocation could generate subtle general equilibrium effects in other sectors that could potentially generate some (small) spillover effects (either positive or negative) for the rest of the world via price changes.

governments may respond to a subsidy agreement by weakening regulations to maintain harvest levels.

The situation is quite different in fisheries with low depletion potential. These are fisheries where the governments' desired employment level is lower than that which supports the maximum sustained yield in the absence of regulations. In Figure 1, if we let $\alpha = \bar{\alpha}$, then a government that focussed only on employment benefits (net of the opportunity cost of labour) would choose an N to the left of $r/2\bar{\alpha}$. This means that unlike in the previous section, H and N can no longer be targetted independently. Given N, the maximum potential harvest is constrained by technology because there is a ceiling on harvesting productivity $\bar{\alpha}$. The government faces the constraint

$$H \leq H(N, \bar{\alpha}) \qquad (41)$$

where $H(N, \bar{\alpha})$ is the sustainable harvest function given by (6). In particular, H_{MSY} is not feasible when N < $r/2\bar{\alpha}$. One way to think about this is that these are fisheries that are difficult to harvest with the available technology ($\bar{\alpha}$ is low). Governments may still want to subsidize such fisheries, but even with subsidies, employment in the fishery will not be sufficient to generate harvests that threaten the fish stock. As a result regulations may not be used. And when regulations are not used the analysis is much like that in Section 3 where only subsidies are available.

Assuming that there is low depletion potential, the Home government's problem is to choose N and H to maximize (24) subject to the constraint in (41) and for given H* and N*. If the constraint binds,[37] then the first order condition for the choice of N can be written as

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[37] The constraint (41) will not bind if there is very strong market power. This will be the case if (29) and (31) hold and (41) does not bind. That is let N_1 solve (29) and H_1 solve (31), and suppose $H_1 < H(N_1, \bar{\alpha})$. The level of employment N_1 desired by the government to satisfy the employment motive is more than enough to produce the harvest level H_1 that best exploits the country's market power. This means that (41) does not bind and the government is able to independently target H and N. A subsidy is chosen to support N_1 and regulations are imposed to reduce the harvest to H_1. In this case Proposition 4 (iii) will hold - the exporting countries can benefit from an agreement to reduce subsidies because they are not internalizing the terms of trade effects of their choice of harvest on their rival.

$$pH_N(N,\bar{\alpha}) - w + \lambda\varphi'(N) + E\frac{dp}{dN} = 0 \tag{42}$$

Note that we can write the first order condition for the choice of a subsidy (11) from Section 3 as[38]

$$\left[pH_N(N,\bar{\alpha}) - w + \lambda\varphi'(N) + E\frac{dp}{dN}\right]\frac{dN}{ds} = 0 \tag{43}$$

Comparing (43) and (42) confirms our claim that the government behaves much like that in Section 3. There are two instruments available but if the fishery has low depletion potential, regulations are not used so that there is effectively only one relevant instrument (the subsidy) as in Section 3. Moreover, when there is low depletion potential we have N to the left of $r/2\bar{\alpha}$ in Figure 1 and this means that we are on the upward sloping part of the supply curve. An increase in one country's subsidy (or employment) raises harvest levels which pushes down the price and harms the other exporter. This means that we are in the standard case where exporting countries have an incentive to agree to reduce subsidies to reap the terms of trade benefits. And since regulations are not being used in equilibrium, such an agreement would be effective because it can't be undone by relaxing regulations. Hence fisheries with low depletion potential are good candidates for an agreement on subsidies.

6. Subsidies in fish-importing countries

We have focussed on the potential for an agreement among fish-exporting countries to reduce subsidies. In this section we briefly consider fish importing countries that also harvest their own fish. The key difference is in the sign of the international spillover effects of a reduction in subsidies. Lower fish prices harm fish exporting countries but improve the terms of trade for fish-importing countries.

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[38] Since p depends on H, and H depends on N, we have used $\frac{dp}{ds} = \frac{dp}{dN}\frac{dN}{ds}$.

If governments are unable to implement and enforce fishery regulations then the potential for subsidy agreements is essentially opposite to what we found in Section 3. If employment motives are weak and fish-importing countries are on the upward sloping portion of their supply curves, then subsidies act like second-best tariffs because they push down import prices. An agreement to reduce subsidies would worsen the terms of trade for fish-importing countries and so would only be feasible if tied to a larger trade agreement. On the other hand, if there is a strong employment motive and the fish importing countries are on the downward sloping part of their supply curve, then an agreement to reduce subsidies would lead to increased long run harvests (because the stocks would recover). This would reduce import prices and benefit fish-importing countries. This suggests that there might be more potential for an agreement to reduce subsidies among fish-importing countries with depleted stocks than for such an agreement among fish exporters.

If fish importing countries have access to effective fishery regulations and if the employment motive is strong enough to generate subsidies, then for fisheries with strong depletion potential, the conditions[39] for the government's choice of N and H□ (given H* and N*) are given by

$$\lambda\varphi'(N) = w \tag{44}$$

and

$$H = H_{MSY} \qquad if \;\; p^D - Mp_H^D > 0 \text{ at this level of H;} \tag{45}$$

$$p^D - Mp_H^D = 0, \qquad \text{otherwise} \tag{46}$$

where M denotes home imports (M = D-H).

Note however that with M > 0, we have $p^D - Mp_H^D > 0$ as long as the price is still positive, so (46) does not apply. The solution is therefore to choose policies to support the largest sustainable harvest. This differs from the case of exporters in that once the

[39] This follows the analysis that lead to (29) - (31).

employment motive is satisfied, governments always want to produce at the MSY level (assuming the harvesting technology is sufficiently productive to facilitate this). An increase in harvesting is always beneficial because it lowers import prices and benefits domestic consumers. There is no incentive for fish importers to support an agreement to reduce subsidies because either it would be ineffective due to adjustments in fishery regulations or else it would worsen their terms of trade. If a subsidy agreement was tied to a broader trade agreement, then we would expect it to be undermined by the incentives to adjust domestic fishery regulations.

7. Conclusion

At first glance, the case for reducing subsidies in fisheries may seem to be compelling. Many fisheries throughout the world have collapsed, and studies such as Worm et al. (2009) argue that current pressures on fisheries will increase and lead to further collapse. Standard economic analysis highlights stock externalities in fishing and typically calls for taxes (not subsidies) to internalize these externalities. And even if we concede that governments are motivated by political and redistributive motives, the standard analysis of trade agreements (Bagwell and Staiger, 2001a) points out that regardless of a government's objective function, there is always potential for international agreements to coordinate or at least partially constrain interventionist policies as long as international spillover effects exist.

We develop a simple model in this paper to show how achieving international agreements to reduce fishery subsidies may be more challenging than for many other types of subsidies. There are three reasons for this.

First, the usual argument for reducing subsidies in open economies is that it is in the interest of the subsidizing governments to do so. This is because of the Prisoner's dilemma. Governments subsidize to promote employment or output and one country's subsidy undermines other governments' attempts to achieve their employment and output targets by lowering prices. In the case of fisheries, this is unlikely to happen for heavily exploited fisheries because subsidies will lower long run output (via stock depletion) and *raise* prices. That is, one government's subsidy does not undermine other governments' attempts to promote employment in their fisheries and so subsidizing governments need not stand to gain from an agreement to curtail their use. Instead importing countries would stand to gain and this will require a different set of concessions than in the typical case of subsidy negotiations.

Second, we find that even if subsidized fisheries are well-regulated (in the sense that the fish stock is not in danger) then there may be no incentive for fish exporters (or importers) to come to an agreement to reduce subsidies. The use of fishery regulations can protect fish stocks in the presence of subsidies. And ecological constraints place a cap on sustainable harvests. When exporters can influence world prices, subsidies typically lead to overproduction as each country ignores the effects of its output on the terms of trade for other exporters. However, in the fisheries case, ecological constraints put an upper bound on sustainable production for each fish stock and this means that over-production (from the perspective of terms of trade issues) is much less likely to be an issue in well-managed fisheries. Consequently there may be no incentive for the subsidizing countries to come to an agreement to reduce these subsidies. Each government is acting in accord with its objectives and there are no international spillover effects to internalize via global negotiations.

And third, an agreement to reduce subsidies may end up being at least partially undermined by the affected countries unless the WTO were to also get into the business of fisheries management. This is because a government that has a political objective to promote employment in the fishery can respond to a directive to reduce subsidies by weakening other forms of fisheries regulation. That is, once subsidies are constrained, governments can look for other ways to support fishers.

There is much scope for further work on these issues. The current paper considers only fisheries that do not fall under the jurisdiction of multiple countries. In ongoing work, we consider shared fisheries. In this case, countries are linked via two channels: terms of trade effects and stock effects; and hence the potential for international coordination is more complex. And while we focus on international spillovers as the motive for negotiation, there are other possibilities. International agreements can also be used as a commitment device by governments who anticipate being subject to political pressures in the future (see Maggi and Rodriguez-Clare, 1998). If the aggressiveness of fishery regulation is endogenous, then international agreements could potentially play a role in helping governments maintain more effective regulation.

Appendix

Proof of Proposition 2.

The home government objective is

$$W = V(p) + pH + \lambda\varphi(N) - wN$$

The first order condition for N yields

$$\lambda\varphi'(N) = w$$

For H, we have at an interior solution

$$\frac{\partial W}{\partial H} = Ep_H^D(H + H^*) + p^D(H + H^*) = 0$$

However if this implies an $H > H_{MSY}$, then the MSY constraint binds and the solution is $H = H_{MSY}$. Finally, because we have assumed that the fishery has strong depletion potential, the level of employment chosen by the government will be high enough to support and $H \leq H_{MSY}$ at a feasible level of α.

Proof of Proposition 3.

Joint government welfare is

$$W + W^* = V(p) + pH + \lambda\varphi(N) - wN + V^*(p) + pH^* + \lambda^*\varphi^*(N^*) - w^*N^*$$

Totally differentiating and rearranging yields:

$$dW + dW^* = \left[(E + E^*)\,p_H^D + p^D\right](dH + dH^*)$$
$$+\lambda\left[\varphi'(N) - w\right]dN + \lambda^*\left[\varphi^{*\prime}(N^*) - w^*\right]dN^*$$

The first order conditions require that we differentiate W+W* with respect to each of the 4 policy variables s,s*,α, and α^* and set equal to zero. These conditions will be satisfied by choosing policies so that

$$\lambda\varphi'(N) = w$$

$$\lambda^*\varphi^*{}'(N^*) = w^*$$

and_either by making H and H* as large as possible (in which case dH + dH* = 0) or by choosing H and H* such that

$$\left(E + E^*\right) p_H^D + p^D = 0.$$

The former is the solution if

$$\left(E + E^*\right) p_H^D + p^D > 0$$

at the MSY levels of H and H*. The latter is the solution otherwise.

Note that one could alternatively obtain the same solution by choosing H,H*, N and N* directly to maximize W+W* subject to the MSY constraints and then implementing with the available policy instruments.

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