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Abstract. Many renewable resource sectors are heavily subsidized and yet the resources are also seriously depleted. World Trade Organization members included subsidies in a key renewable resource sector (fisheries) 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, open access fishery supply curves are backward bending and so if fisheries are depleted, subsidies raise prices (by reducing sustainable harvesting) and improve other exporters' terms of trade. Second, ecological constraints put an upper bound on sustainable harvesting. This means that subsidies that increase employment may have no effect on output and hence generate no international spillover effects if resources are well managed. And third, even if governments were compelled to reduce fishery subsidies, there may be no spillover benefits to trading partners because of policy substitution: governments would be motivated to weaken other regulations targeting the fish sector.

Keywords: trade agreements, fisheries, renewable resources, subsidies, transferable quotas

JEL- Classification: F18, F53, Q22, Q27

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1. Introduction

Many renewable resource sectors are heavily subsidized and yet the resources are also seriously depleted (OECD, 2003). Fisheries subsidies are pervasive and have influenced fish stock depletion. Deforestation in Brazil, Indonesia and parts of Africa has been influenced by subsidies for both logging and land-clearing. Subsidies for the use of groundwater deplete the stock of water and threaten the sustainability of agriculture.[1] Outputs from the renewable resource sector are heavily traded and subsidies influence both the pattern and gains from trade.

This suggests that there ought to be potential for international agreements to curtail subsidies in the renewable resource sector; and indeed the Doha conference launched negotiations to clarify and improve World Trade Organization (WTO) disciplines on subsidies in a major renewable resource industry – fisheries. However the negotiation process has stalled.[2] 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. Although we focus specifically on fisheries for concreteness and because of the stalled negotiations directly targeting that sector, our results have implications for other renewable resource sectors, as we discuss in the concluding section of the paper.

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

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1 On fisheries see Pauly et al. (2002); on deforestation see Repetto (1988), OECD (2003), Contreras-Hermosilla (2000), and Porter (1997); and on water see Porter (2003).

2 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). Negotiation efforts continue with a new goal to obtain an agreement on disciplining harmful subsidies by 2020 (Fisheries Bridges, 2017).

grown substantially, particularly in Europe and East Asia. They reached levels of US$35 billion in 2009 (Sumaila et al., 2016).[3] Capacity-enhancing subsidies (which reduce cost or increase revenue for fishers)[4] represent 57% of total subsidies. The largest subsidies are provided by Europe, Japan and China.[5] Many analysts contend that subsidization is contributing to the high rate of fisheries depletion (Sumaila et al., 2007). Pauly et al. (2002) give several examples where subsidies have contributed to stock depletion; notably the eastern Canadian cod fishery where subsidies were in part motivated by employment.[6] Using data from 23 OECD countries for the period 1996–2011, Sakai (2017) finds that cost-reducing subsidies reduced stocks in fisheries not managed with quotas. Why then is it so difficult to negotiate agreements to reduce subsidies?

To answer this question we develop a model where politically-motivated governments implement fisheries subsidies, perhaps in conjunction with other resource management tools. We use a simple Grossman-Helpman lobbying model in which a community group lobbies the government for subsidies to promote employment in the fishery. We embed this structure in an international trade model that allows us to analyze the spillover effects of subsidies across countries. Our focus is on fish exporting countries, although also we briefly discuss the case of importers. We find the non-cooperative equilibrium in subsidies, and analyze incentives to negotiate agreements to reduce subsidies.

For most of the paper, we consider fish stocks that lie entirely within the jurisdiction of single countries. Interaction between countries occurs via prices and this allows us to focus on trade-related issues. In section 7 we consider transboundary fish stocks – in this case, countries are linked both via prices and international fish stock externalities and this creates additional incentives for international agreements.

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[3] There have been other estimates of fisheries subsidies: Milazzo (1998), OECD (2006), Sumaila and Pauly (2006), Sumaila et al. (2010 a,b) and Schuhbauer (2017).

[4] Examples include fuel subsidies, lending programs, support for boat construction, renewal and modernization, price support programs, and tax exemptions. See Sumaila et al. (2010b).

[5] Sumaila et al., (2016). These three regions collectively account for 68% of global subsidies.

[6] In 1985, the United States launched a countervailing duty action, claiming that numerous Canadian subsidies harmed US fisheries. Several of the subsidies promoted employment – among them was the contention that the Canadian Unemployment Insurance program was structured to promote seasonal employment in the fishery. See Anderson and Rugman (1987).

In the standard trade agreement literature (such as Bagwell and Staiger, 1999), 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.[7] 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 this paper we highlight three aspects of renewable resource markets that make the potential for international agreements on subsidies different and potentially more difficult than in other sectors.

The first is that the terms of trade effects induced by changes in subsidies can move in the opposite direction to that in other markets. This situation is most likely to arise in fisheries where there is little effective management capacity. Because open access 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. This is opposite to the usual presumption that subsidies lower prices and harm other exporters. Hence the incentives for exporters to negotiate an agreement to internalize price spillover effects in depleted fisheries may either be non-existent or perverse. Importers, however, would benefit from a reduction in subsidies because this would lead to a long run increase in sustainable harvesting (and hence lower prices). We show that there is potential for a global agreement to reduce subsidies, but it would

[7] International spillovers are not the only motive for international agreements on subsidies. Another rationale arises from commitment benefits. A government that expects future political pressure to implement inefficient policies can use an international agreement as a commitment device to help withstand this pressure (see Maggi and Rodriguez-Clare (1998) on the commitment approach, and Brou and Ruta (2013) on its application to subsidy rules). The application of this approach to renewable resources is an interesting subject for future research.

require concessions from importing countries.

Not all subsidized fisheries are depleted, and hence the terms of trade channel outlined above will not be operative if fisheries are well managed. We show that there is limited potential for agreements to reduce subsidies in this case as well because of a second distinctive feature of renewable resource markets: ecological constraints put a cap on sustainable output. In most markets subsidies lead to excessive production, which lowers prices. In renewable resource markets, subsidies that stimulate employment may have no effect on output if accompanied by regulations that prevent overharvesting. This can eliminate international spillover effects from subsidies. We find that in some cases the cooperative equilibrium yields the same outcome as the non-cooperative equilibrium so that there is no incentive to negotiate an agreement to reduce subsidies.

A third way that subsidy negotiations can be challenging in renewable resource markets is that an agreement to reduce subsidies provides 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 ecological constraints on the fishery provide a binding cap on harvest levels, and this can make each government's desired harvest levels unresponsive to changes in price or subsidy constraints – any agreement to reduce subsidies would be completely undermined by weaker fishery regulations.

After analyzing the distinctive features of renewable resource markets that create challenges for subsidy negotiations, we then consider the types of agreements that could be effective. We show that an agreement among countries that directly targets country-level harvests would be effective and efficient. While international agreements that place restrictions on output are undesirable and inefficient in most markets, they are a natural response to sustainability concerns in renewable resource markets. We also show that if such an agreement is feasible, restrictions on subsidies are not needed.

Previous theoretical work[8] has considered the effects of fisheries subsidies, but has not explicitly focused on the incentives to negotiate that we emphasize. Clark et al. (2005) 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), Bulte and Damania (2005), Munro (2007), Pintassilgo et al. (2010), Rus (2012), and Takarada et al. (2015)]. 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 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.

As noted above, in the international trade agreement literature (such as Bagwell and Staiger, 2001b), subsidies typically lower prices and worsen exporters' terms of trade. A key factor driving some results in this paper is that subsidies can result in an *increase* in prices and hence a terms of trade improvement in renewable resource markets because of resource stock depletion. In a very different context, Bagwell and Staiger (2012, 2015)

[8] There is also an empirical literature documenting the effects of subsidies. Sumaila et al. (2010a) 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. And as noted above, Sakai (2017) finds evidence that subsidies contribute to depletion in fisheries not subject to quotas.

show that an export subsidy can improve a country's terms of trade in a firm delocation model – Home's export subsidy leads to exit of firms in Foreign, pushing up the price there (although Home's domestic price falls because the subsidy induces entry).

We set up the model in Section 2. Section 3 focuses on the terms of trade channel and considers governments that lack effective management capacity. Section 4 considers governments that have effective resource management and shows how the cap on sustainable harvesting due to ecological constraint can eliminate international spillover effects from subsidies. Section 5 considers policy substitution. The design of efficient agreements is discussed in section 6. This is followed by three extensions to the model. Importers that harvest fish are considered in section 7.1, individual transferable quotas (ITQs) are considered in section 7.2, and shared fisheries are briefly studied in section 7.3. Section 8 summarizes our main results and draws some policy conclusions. The appendix contains proofs and a brief discussion of transitional dynamics.

2. The Model

We develop a simple model in which politically motivated governments subsidize employment in the fishery sector. Throughout most of the paper, policy instruments include taxes, subsidies, and a set of regulations that raise the cost of fishing.[9]

We assume that governments choose policies to maximize steady state returns and implicitly assume that the discount rate approaches zero.[10] International agreements are long-term commitments, and a focus on steady states allows us to highlight long run issues in a very simple way.[11] The case where the discount rate approaches zero is a useful benchmark because it implies that governments choose rules that maximize sustained well-being, taking into account employment objectives. This allows us to

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[9] The implications of using individual transferable harvest quotas (ITQs) are considered in Section 7. Arnason (2012) estimates that about 25% of global fish harvest is covered by ITQs, which nevertheless means that about 3/4 of 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.

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

[11] We briefly consider transitions between steady states in Appendix II.

highlight difficulties in reaching subsidy agreements even when governments are not short-sighted.

We begin with a non-cooperative equilibrium between governments and use this as a benchmark to evaluate incentives to negotiate agreements to reduce subsidies. Our assumption that government objective functions depend on steady state values abstracts from intertemporal strategic effects, but its relative simplicity allows us to highlight several strategic issues that distinguish subsidies in fisheries from subsidies in other commodities. This approach of analyzing the fishery as a non-cooperative game in an essentially static framework was used by Mesterton-Gibbons (1993) who focused 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.[12] This approach has also been used by Bagwell and Staiger (2012) in the literature on trade agreements. In their model there is a fixed stock of firms in the short run but changes in trade policy induce entry and exit in the long run. Governments engage in a non-cooperative game in trade policy where their objective functions depend on long run outcomes and hence are implicitly a function of steady state values.

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.[13] In section 7 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 for the country with a quasi-linear indirect utility function U that takes the form

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[12] See also Pintassilgo and Lindroos (2008) and Kronbak and Lindroos (2006).

[13] A three country approach was 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.

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

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

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

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 available to government: (1) taxes or subsidies for fishers; and (2) regulations that increase the cost of fishing.[14]

In practice, subsidies take many forms, most of which can be thought of as reducing costs. Because 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.[15] We allow *s* to be positive or negative; if $s < 0$, then it is a tax.

We use a slightly generalized version of the Schaefer (1957) fisheries model.[16] We assume fishers differ in productivity. Fishers are indexed by n, and are ordered so that productivity is decreasing in n. The harvest (per period) for a typical fisher n is

$$h(n) = \alpha(R)a(n)XL(n) \tag{1}$$

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[14] Our approach is motivated by Homans and Wilen (1997). Grainger and Costello (2016) and Takarada et al. (2015) also adopt this approach to modeling regulation.

[15] 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 support fishing communities, and so on. All of these create incentives for marginal fishers to enter 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.

[16] This is a standard model in the fisheries literature - see for example Clark (2010); it has also been used in the trade and fisheries literature (Brander and Taylor, 1997).

where X is the stock of fish (harvesting productivity is increasing in the stock) and $L(n)$ is labour supply of fisher n. The term $\alpha(R)a(n)$ measures the productivity of fisher n. It has two components. There is a common across fishers productivity term $\alpha(R)$ that is decreasing in the intensity of regulation R, and the term a(n) captures the fisher-specific productivity. We assume a(n) is decreasing, continuous and convex in n, and $a(n) \in [0, \bar{a}]$. Regulation raises the cost of fishing for all fishers. 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 that can be caught, and so on. We do not focus on the details of each of these different types 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 □□□□□□□□ and so in what follows, we suppress R to economize on notation.

Because we assume that each fisher supplies 1 unit of labour [i.e., L(n) = 1], then from (1), we have

$$h(n) = \alpha a(n) X \tag{2}$$

With N fishers active, aggregate harvest is

$$H = \alpha A(N) X \tag{3}$$

where

$$A(N) \equiv \int_0^N a(n)\,dn$$

Note that A(N) is increasing and concave in N. 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

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

Note that the stock is extinguished for $A(N) \geq r/\alpha$. We assume that the government must choose policies such that in equilibrium $A(N) < r/\alpha$ (that is, it cannot subsidize employment in a fishery that no longer exists). This is a constraint on government policy; but we focus on interior solutions where the motive to subsidize is not strong enough for the constraint to bind.

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

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

We can now determine the steady state number of fishers N. Recall that each potential fisher has 1 unit of labour with opportunity cost w. There is free entry and so fishers will enter as long as net return per period of fishing is positive. Hence the marginal fisher N is determined by a zero profit condition. Using (2), this can be written as

$$\pi(N,X) = p\alpha a(N)X - w + s = 0 \quad (7)$$

where s is a subsidy (or tax if s < 0) available for each fisher per period of fishing.

The solution can be illustrated in two ways. First, using (5) we can write (7) as

$$p\alpha\bar{X}\left(1 - \frac{\alpha}{r}A(N)\right) = \frac{w-s}{a(N)} \quad (8)$$

Since A(N) is increasing in N, the left hand side of (8) is decreasing in N; and since a(N) is decreasing in N, the right hand side is increasing in N.[17] Hence there is a unique solution for N.

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

An instructive way to illustrate the solution is shown in Figure 1. Since from (3), $\alpha X = H(N)/A(N)$, the free entry condition (7) can be rewritten as

$$H(N,\alpha) = \frac{(w-s)}{p}\frac{A(N)}{a(N)} \tag{9}$$

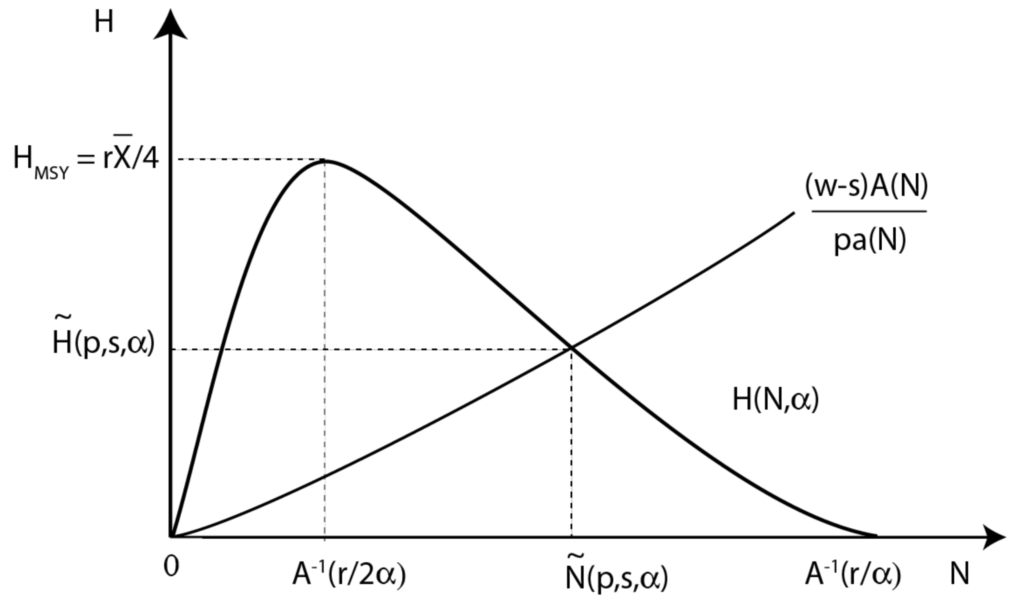

Figure 1. Free entry equilibrium determines H and N.

The left hand side of (9) is the sustainable harvest function (6). It is hump-shaped and skewed to the left as illustrated in Figure 1. Given regulations (and hence given α), an increase in the number of fishers (N) initially leads to an increase in harvest. These are the most productive fishers. The harvest level peaks and then eventually declines to zero as N increases because of stock depletion. Because the productivity of fishers is decreasing in N, each entrant has a successively smaller effect on stock depletion, resulting in a harvest function skewed to the left. To find the peak choose N to maximize H in (6). This yields

$$A(N) = \frac{r}{2\alpha} \quad or \quad N = A^{-1}\left(\frac{r}{2\alpha}\right) \tag{10}$$

where A^{-1} is the inverse function of A. Substituting this into (6) yields

$$H_{MSY} = \frac{r\bar{X}}{4} \tag{11}$$

The maximum sustainable harvest, which we have denoted H_{MSY}, is known in the fisheries literature as the "maximum sustainable yield" (MSY)[18]. As noted above the stock is totally wiped out if $A(N) \geq r/\alpha$ on a sustained basis. This puts an upper bound on sustainable employment in the fishery for given α.

The right hand side of (9) measures the cost of catching H(N) from the perspective of the marginal fisher N. The marginal fisher catches a fraction a(N)/A(N) of overall harvest H. Hence the right hand side of (9) scales up the marginal fisher's opportunity cost of time relative to the price of fish, (w-s)/p, by the number of units of labour that fisher would have to utilize to (hypothetically) catch the overall harvest H(N). This is an increasing function of N, because the productivity of the marginal fisher is decreasing in N.[19] The intersection of this curve with the harvest function H(N) occurs at the point where the marginal fisher makes zero profits. The solution to (9) yields the harvest supply function $\tilde{H}(p,s,\alpha)$ and the employment function $\tilde{N}(p,s,\alpha)$ as illustrated in Fig. 1.

Increases in the price of fish rotate the cost line downward. Starting at a very low price, higher prices increase H, but at some point further price increases lead to a decrease in H. That is, as is well known in the fisheries literature, long run harvest supply curves are 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 $A(N) > r/2\alpha$, 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.

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[18] See for example Clark (2010).

[19] One can show that the cost curve is unambiguously convex for N small. And if the fishery is viable (profitable for the most productive fisher when N approaches zero), then for N near zero, the harvest curve H must be steeper than the cost curve. Finally, we know from (8), that the curves must intersect only once.

More stringent regulations (a reduction in α) stretch the sustainable harvest curve H(N,α) to the right, allowing positive sustained harvesting at higher levels of employment. More stringent regulations, however, do not affect the magnitude of the maximum sustainable yield. H_{MSY} is independent of technology and is determined by ecological constraints.

If there is no regulation and no subsidy, 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 political motive to subsidize the fishery is strong enough to generate positive subsidies in the non-cooperative equilibrium. This will push 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

$$D^W(p) = \tilde{H}(p, s, \alpha) + \tilde{H}^*(p, s^*, \alpha^*) \tag{12}$$

We assume that

$$\tilde{H}_p^* + \tilde{H}_p - D_p^W > 0;$$

that is, we assume stability so that an outward shift in supply lowers prices and an inward shift raises prices. It will be sometimes be convenient to use 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 and lobbying

Governments use subsidies for a variety of reasons, but a reading of the literature 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. Shrank et al. (1992) note that in some regions, fisheries are viewed as an "employer of last resort". We will therefore assume that the government faces political pressure to weigh 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. This means that in the absence of political pressure to maintain employment and if there were no terms of trade effects, 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 needed to fund the subsidy is sN. We assume that the subsidy is financed via lump sum taxation so that the social return to the fishery net of subsidies or taxes is given by Π.

We formalize the political motive for subsidies with a very simple lobbying model based on Grossman and Helpman (1994) in which lobbies offer campaign contributions in return for policies. We assume a single issue lobby group that promotes employment in the local fishery – it could for example be a local community group in a town dependent on the fishing industry or it could be a fishers' association. The sole objective of the lobby group is to promote employment in the fishery. The lobby's objective function is

$$W^L = \varphi(N) - C$$

where φ is increasing and concave in employment N and C is the level of campaign contributions.[20] The government weighs social welfare and campaign contributions when choosing policy. Its objective W^G is

$$W^G = W^S + \lambda C$$

[20] Campaign contributions are financed by lump sum payments from members of the lobby group. These contributions are made independently of whether or not one is a fisher.

where W^S is social welfare, and λ is the weight the government puts on contributions. The parameter λ represents the strength of the political motive.

We follow Goldberg and Maggi's (1999) solution to the Grossman-Helpman lobbying model and assume that the government and lobby reach an efficient bargain. Given the quasilinearity of the objective functions, this implies that the government will choose policies to maximize the joint surplus of itself and the lobby group.[21] That is, the government's objective becomes:

$$W = W^S + \lambda\varphi(N)$$

We have a partial equilibrium model, and so social welfare is the sum of consumer surplus V(p) and resource rents. Hence we have:

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

Because lobbying leads to an efficient bargain, the harvesting externality is internalized when choosing policy. Policies balance the surplus generated from the fishery against pressure from the lobby group to increase employment. Although increased employment may lead to stock depletion (depending on what regulatory instruments are available), this effect is internalized.

With the model in hand, we now proceed to illustrate three aspects of the renewable resource sector that reduce or eliminate the incentives for exporting countries to participate in agreements to reduce subsidies.

3. Terms of trade effects and the potential for subsidy agreements in open access fisheries

As Bagwell and Staiger (1999) emphasize, spillover effects of policies across countries

[21] An efficient bargain requires that policy maximizes W^G for any given return to the lobby $\bar{W}^L$. That is, policy must maximize $W^G = W^S + \lambda C$ subject to $\varphi(N) - C = \bar{W}^L$ for any given $\bar{W}^L$. Substituting the constraint into the objective yields $W^G = W^S + \lambda\varphi(N) - \lambda\bar{W}^L$. Hence policy will be chosen to maximize $W^S + \lambda\varphi(N)$.

provide a key motivation for trade agreements. Subsidies generate spillover effects by affecting world prices. In standard models, subsidies tend to decrease world prices. In the renewable resource sector, resource depletion leads to backward bending supply curves and as a result subsidies can lead to increases in world prices. In this section, we show how this channel implies that the incentives to negotiate agreements on subsidies in an open access renewable resource sector are very different than in most other sectors.

To highlight the role of terms of trade effects, we focus on subsidies (or taxes) and assume that other regulations are exogenous (that is, in this section of the paper, we set $\alpha = \bar{\alpha}$). This is a case where governments' capacity for resource management is weak. We focus on the Home government's problem; the Foreign government solves an 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 (9), treating the foreign subsidy as given. Noting that we can write

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

the first order condition yields[22]

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

where $E \equiv H - D$ is net exports of fish, with D denoting domestic demand for fish. In (15), dN/ds is the full effect of s on N, taking into account the effect of s on the price of fish. From (6) and (9) 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 dampens the increase

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

in N, but will not reverse it if the market is stable. We will discuss this in more detail below when we analyze the sign of dp/ds.[23]

We can use (15) to solve for the Home government's optimal subsidy (given s*):

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

There are three terms, reflecting three different motives for policy intervention.

First suppose the price of fish was fixed and there was no employment motive. This would leave just the first term in (17) and we would have:

$$s = p\alpha A(N) X_N < 0$$

In this case the optimal policy is a harvest tax that fully internalizes the harvest externality (the stock depletion caused by an additional fisher reduces the productivity of all other fishers). This is a standard result from the fisheries literature.

The second term in (17) (which is positive) reflects the political benefits perceived by the government from increased employment in the fishery.

The final term in (17) is the terms of trade effect. Since Home exports fish, it has an incentive to manipulate the subsidy to increase the price of fish. If a subsidy reduces the world price of fish, then the final term is negative and the terms of trade motive reinforces the case for a tax. However, as we show below, a subsidy in an open access fishery can 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. Equilibrium subsidies could be positive or negative. If employment motives are sufficiently strong (i.e. λ and λ* sufficiently large) then they dominate the other effects and governments will subsidize the fishery (this is verified in the proof of Proposition 1). We assume that this is the case

[23] See footnote 24.

in all of what follows because we want to analyze the incentives to come to an agreement to reduce subsidies.

Terms of trade effects

The key to the analysis is the sign of the terms of trade effect. The effect of an increase in Home's subsidy on the world price of fish is found by using (12) to obtain:

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

As discussed above, supply curves are backward bending in open access fisheries. A subsidy encourages entry, and for given stock levels, this increases output. But increased harvesting 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:

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

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.[24]

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 will happen, refer to Figure 1. Given s, 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), equilibrium employment could be either to the left or the right of the point that generates the maximum sustainable harvest (H_{MSY}). 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.

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

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 (9)) and we are treating regulations and hence α* as given. W* does not depend directly on Home's subsidy *s*, but does so indirectly via the effect of Home's

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[24] At this point we can verify the claim that dN/ds > 0 as discussed after equation (16). Let $\Delta \equiv \tilde{H}^*_p + \tilde{H}_p - D^W_p$. 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 $1 - \tilde{H}_p/\Delta = \left(\tilde{H}^*_p - D^w_p\right)/\Delta > 0$ and also $\tilde{N}_s > 0$ and so dN/ds > 0 as claimed.

subsidy on the price of fish. 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[25]

$$\Psi^* \equiv \left[\frac{N_{s^*}^*}{N_{s^*}^* + N_p^* p_{s^*}} \right] > 0 \ . \tag{21}$$

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, 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 weak, and the fisheries are relatively underexploited, both countries will operate in the region where their harvest supply curves are upward sloping. This is a case 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. Each exporter's subsidy generates a negative spillover effect for the other exporter. 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

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[25] The Foreign government's first order condition for s* is $W_p^* p_{s^*} + W_{s^*}^* = 0$. Use (19) to find W_p^* and $W_{s^*}^*$. This can be used to show $W_p^* = E^* + W_{s^*}^* N_p^* / N_{s^*}^*$. Using the first order condition to eliminate $W_{s^*}^*$ yields (20). The positive sign of Ψ^* in (21) follows because market stability implies $N_{s^*}^* + N_p^* p_{s^*} > 0$ using the same argument as in the previous footnote.

country's subsidy reduces the world supply of fish and 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:

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

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 $\underline{\lambda}$□□□□ $\underline{\lambda}$□□□□□□□□□□□□□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.//

Proof: See Appendix I.

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.[26,27]

While exporting countries have no incentive to negotiate agreement among themselves to reduce fish subsidies, there is nevertheless scope for a broader international agreement. When fisheries are depleted beyond the Maximum Sustained Yield level, subsidies reduce long run harvest. This increases fish prices and harms importers. That is, the subsidies create terms of trade spillover effects for the rest of the world, and this creates incentives for a WTO-facilitated agreement to constrain subsidies. To see this formally, let W^{ROW} indicate the welfare of fish importing countries. Then the effect of a change in Home's subsidy on global welfare[28] is

$$\left.\frac{d(W+W^{*}+W^{ROW})}{ds}\right|_{dW/ds=0} = \underset{(+)(+)}{W_p^{*}\frac{dp}{ds}} + \underset{(-)\;\;(+)}{W_p^{ROW}\frac{dp}{ds}} \quad if \;\; \frac{dp}{ds}>0 \tag{24}$$

An efficient international agreement would internalize the effects of subsidies on all countries, including fish importers. Because the subsidy harms importers, this would lead to a lower subsidy than the exporting countries would choose if they were not negotiating with importers. Such an agreement would not necessarily lead to an elimination of subsidies, because the agreement would reflect the preferences of

[26] Although the fisheries are "depleted" in this equilibrium, they are nevertheless sustainable. Both governments internalize the effects of their subsidies on their own fish stocks. Referring to Figure 1, an employment level $\tilde{N}$ is supported by a sustainable harvesting strategy with a sustainable fish stock given by (5). The stock is below both the natural unexploited level and the level that would support the MSY harvest, and for this reason, there may be ecological risks. A more general model could incorporate stochastic elements to reflect these risks; but such a model could also incorporate governments that may not fully internalize these risks. We leave these issues for future work.

[27] There may 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 consensus among fish exporters in favor of an agreement to reduce subsidies.

[28] We have assumed quasilinear utility so an efficient agreement would maximize joint surplus. And note that an agreement would involve a joint agreement on s and s*.

politically motivated governments. However as Bagwell and Staiger (1999) emphasize, the presence of international spillover effects via terms of trade effects creates incentives even for protectionist governments to negotiate agreements.

Although the potential for global negotiation exists, these results highlight why negotiations on fish subsidies differ from subsidies in other contexts. In other sectors, an exporter's subsidy typically lowers prices. This generates positive spillover benefits for consuming countries and negative spillover effects for other exporters. Exporters would gain from an agreement to reduce subsidies (because it would mitigate the negative spillover effects) and no concessions from importers are needed. In the case of fisheries, the spillover effects can be reversed, so that exporters would lose from an agreement unless suitably compensated by importers.

4. Ecological constraints, regulation and the potential for subsidy agreements

The above analysis applies to countries with little capacity to enforce effective fishery regulations. In practice, many governments are able to engage in effective resource management. In this section we 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.

Effective resource management ensures that the supply curve is not backward bending (because it prevents excessive resource depletion). This eliminates the channel analyzed in the previous section that led to positive terms of trade spillover effects across exporters from increased subsidies. However there is another channel that can render subsidy negotiations unattractive. In most sectors subsidies lead to excessive production. In the renewable resource sector, ecological constraints put a cap on sustainable production. In the case of fisheries that cap is the MSY level of harvesting. We show that effective resource management in the presence of this ecological constraint can both eliminate spillover effects across countries from subsidies, and result in the non-cooperative equilibrium being the same as the cooperative outcome. Hence there is no incentive to negotiate reductions in subsidies.

We proceed by finding the non-cooperative equilibrium when governments choose both fishery regulation and subsidies, and then comparing it with the cooperative solution.

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

$$W = V(p) + pH + \lambda\varphi(N) - wN \tag{25}$$

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

$$N^{\lambda} > A^{-1}\left(\frac{r}{2\bar{\alpha}}\right) \tag{26}$$

where

$$\lambda\varphi'(N^{\lambda}) = w \tag{27}$$

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. Condition (27) 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 $A^{-1}(r/2\bar{\alpha})$ in (26) 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 in equilibrium because regulations can be tightened up to reduce α and protect fish stocks even at high levels of employment.

In what follows we focus on fisheries with high depletion potential in both Home and Foreign. This is the most interesting case, because the incentives to reduce subsidies are very different than for other goods (such as for agricultural products).[29]

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 employment 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 an 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 policy instruments.[30]

A key issue that drives much of the following analysis is that the maximum sustainable harvest is capped by ecological constraints. Recalling Figure 1, the maximum sustainable yield is denoted H_{MSY}. Given a target employment level N, the government can

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[29] When there is low depletion potential, regulations are not needed because the fish stock is not threatened even when there are subsidies. Countries will be on the upward sloping part of their supply curves and the incentive to negotiate subsidies is much like that for other commodities.

[30] To see that this is feasible, let $p^D(H+H^*)$ denote the inverse global demand for fish. Then (given H*) if Home wants to implement some H and N, the required subsidy is given by the free entry condition (9) which implies $s = w - \left[a(N)p^D(H+H^*)H/A(N)\right]$. The required α is determined by the sustainable harvest function (6). Because (6) implies that H is a hump-shaped function of α (given N), α is in general 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.

implement H_{MSY} (if it turns out to be optimal) with appropriate choice of regulations. Using (10), the harvest level will be H_{MSY} if:[31]

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

We are now ready to solve the Home government's problem. Given H* and N*, it chooses H and N to maximize (25) subject to $H \leq H_{MSY}$.

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

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

$$p^D + Ep_H^D = 0, \qquad \text{otherwise} \tag{31}$$

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

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 can target both of these directly. 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).

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[31] Recall that there is an upper bound on harvesting productivity: $\alpha \leq \bar{\alpha}$. This means that we may not be able to find a feasible α to satisfy (28) if N is very low. However we are focusing on cases with strong depletion potential, which from (26) means that N is large enough so that (28) can be supported by a feasible α.

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_H^D 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 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 consumers in the rest of the world. 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 is sufficiently strong), the government will choose a stock level that maximizes the sustained yield from the fishery. This is a policy often advocated by biologists and fishery managers but criticized by economists as being inconsistent with economic efficiency.[32]

We now consider the feasibility of a subsidy agreement by finding the joint optimum for the two exporting countries. It is sufficient to find the conditions that maximize W+W*.[33]

Proposition 3. Assume that the weight on employment is sufficiently strong that both countries want to use subsidies in the joint optimum for the two exporting countries 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

$$H = H_{MSY} \qquad if \;\; p^D + \left(E + E^*\right) p_H^D > 0 \quad \text{at this level of H;} \tag{33}$$

[32] In a different context, Takarada et al. (2015) also find that countries may choose regulations that yield the MSY outcome. They consider the transition from autarky to free trade in a shared fishery when regulations determine harvesting productivity. They do not consider subsidies.

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

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

where E+E* is the sum of Home and Foreign exports. Analogous conditions apply to the Foreign country.

Proof: see Appendix I.

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 in the cooperative and non-cooperative equilibria. 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. That is, we have:

Proposition 4. Suppose governments can choose both regulations and subsidies. If (i) governments put a sufficiently high weight on employment in the fishery, (ii) fisheries in both Home and Foreign have strong depletion potential, and (iii) market power is not too strong (that is if the MSY constraint binds in the joint optimum so that (32), (33) and their foreign analogue hold), then the harvest levels that maximize the joint welfare of the Home and Foreign country are the MSY levels 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.

Normally when two countries have power in an export market, they have incentives to jointly reduce output and push up the price. The fishery differs because sustained output is capped by the ecological constraint. When (33) holds, the joint marginal benefit of producing more fish is positive at the non-cooperative equilibrium and hence there is no incentive to curtail output in the cooperative outcome. All countries would gain if more fish were produced.[34] Because we are at the maximum sustained yield point, long run harvests are as high as possible.[35] Moreover, there is no motivation for a global

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[34] 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.

[35] In other words, they are at a corner solution in the non-cooperative outcome and this prevents

agreement if the interests of importers are also included. The only spillover to importers is via price. Since outputs are at MSY levels (i.e. are as high as is ecologically feasible), there is no adjustment to output (or employment) that would benefit importers.

5. Policy substitution and the potential for subsidy agreements

In the previous section there is no incentive to negotiate subsidy agreements because under some conditions the cooperative and non-cooperative solutions are the same. However if the MSY constraint does not bind in the cooperative equilibrium [that is, if (34) holds], then the cooperative and non-cooperative solutions for exporters differ. In this case it is jointly optimal for exporters to reduce harvests below the MSY level to push up the price of fish. In this section, we show that an agreement to reduce subsidies may nevertheless be ineffective. This is because of policy substitution – governments can undermine the effects of an agreement to reduce subsidies by weakening fisheries regulation. We show that in some cases, an agreement to reduce subsidies has no effect on harvest levels. It makes both exporters worse off (because it raises the costs of supporting employment targets) and it has no effect on importers.

To illustrate the role of policy substitution in undermining a subsidy agreement, we focus on the case where the MSY constraint does not bind in the cooperative equilibrium [(34) holds], but does bind in the non-cooperative equilibrium [(30) holds]. In the non-cooperative equilibrium, each country is harvesting at MSY levels, but collectively they would benefit by cutting output to improve their terms of trade.

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. Consider 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 r□□□□□□□□□□. Because there is now only one unconstrained policy instrument (regulation), H and N cannot be targeted separately. The free entry condition determines N as a function of H (given H*

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non-cooperative dissipation of their market power (as long as (33) holds).

and s). That is, from (9), N(H;H*,s) is implicitly defined by

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

where recall that $p^D(H+H^*)$ is the inverse global demand for fish, and where A(N)/a(N) is increasing in N.[36]

Home's objective is given by (25). Given s and s*, 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 (MB^H) of increasing H; the right hand side can be thought of as the marginal cost (MC^H) of increasing H via the impact of a change in H on employment via (35).

We illustrate the solution to (36) in Figure 2. Home's choice of H depends on H*; we have illustrated the case where H* is at the non-cooperative level. 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}. Because we are assuming that the MSY constraint binds at the non-cooperative equilibrium, $H_{MSY} < H_0$ 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 using regulations to adjust H if the subsidy is fixed.[37] Adjusting H is 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

[36] 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).

[37] 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.

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 positive in the neighborhood of H_0 because (29) holds and $\varphi'' < 0$.

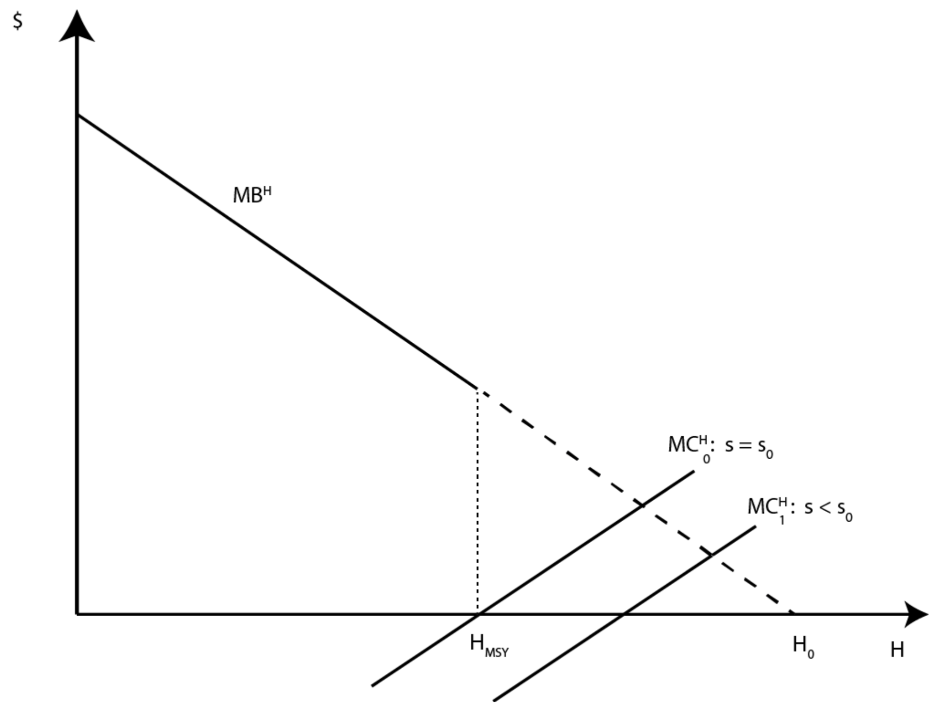

Figure 2. Effect of a change in subsidy when MSY constraint binds

We now want to determine how a reduction in the subsidy affects Home's optimal harvest level H. We focus on relatively small changes in the subsidies for which the MSY constraint continues to bind.[38] 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 (we leave the details to Appendix III[39]), but the

[38] As we show in the appendix, in cases where a reduction in the subsidy shifts up the MC^H curve, a large reduction in the subsidy could result in an outcome where the MSY constraint no longer binds. Except in cases of extremely strong market power this would not yield net benefits as a large drop in employment would be required to generate relatively small changes in harvests and the terms of trade.

[39] We show in the proof of Proposition 5 that the direction of the shift depends on whether an

key point is that because MB^H is vertical, then these shifts have no effect on H – in response to a change in the subsidy, regulations are adjusted to maintain harvesting at the MSY level. That is, a commitment to reduce the subsidy will have no effect on harvest rates because governments respond by manipulating harvest regulations.[40] There are no international spillover benefits or costs from the reduction in subsidies because with H unresponsive, the price of fish will 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 either among themselves or with the rest of the world.

Proposition 5. Suppose governments can choose both regulations and subsidies. If (i) governments put a sufficiently high weight on employment in the fishery, (ii) fisheries in both Home and Foreign have strong depletion potential, and (iii) if the MSY constraints bind at the country level in the non-cooperative equilibrium but not in the cooperative equilibrium (that is (29), (30) and (34) and the foreign analogues hold), then 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 and has no effect on importers.

Proof: See Appendix I.

An agreement to reduce subsidies does not eliminate the political pressures that lead to subsidies in the first place. Such an agreement creates incentives for governments to look for other ways to support fishers, and this can lead to weaker fishery regulations, little or no effect on harvest levels and therefore no net benefits.[41]

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increase in harvest raises or lowers aggregate revenue from the fishery.

[40] 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. 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.

[41] To illustrate starkly the role of policy substitution, we have highlighted the case where a subsidy agreement ends up having no effect at all on output. In other cases, the effect will not be as extreme. As we show in Appendix III, if the MSY constraint does not bind in both the cooperative and non-cooperative outcomes, then an agreement to reduce subsidies can be effective in reducing output. Policy substitution will dampen the effectiveness of a subsidy

agreement, but not completely neutralize it.

6. Achieving efficient agreements

Policy substitution occurs because a subsidy agreement constrains only some of the available instruments, allowing governments to undermine the agreement by adjusting unconstrained policies (fishing regulations). This suggests that there are potential gains from broadening the scope of an agreement to include constraints on fishery regulations. Given government objective functions, an efficient global outcome can be supported by a set of regulations and subsidies, and these could be codified in an international agreement. However an agreement targeting specific regulations is likely to fail. In practice, countries have a wide range of regulatory instruments that can promote fishing effort. Restrictions on some instruments create incentives for governments to substitute toward others. An agreement that attempted to restrict every possible regulatory instrument would be both costly and highly intrusive into the domestic policy regime.

There is a simple and effective alternative – countries could simply agree on country-specific harvest quotas (H and H*), and leave fishery regulations and subsidies unconstrained. Because the price of fish p is determined by H+H*, equation (34) can be implemented by an agreement on country harvest quotas. Moreover, once H and H* are fixed, choosing subsidies and regulations to maximize Home's objective (25) will yield (32). Hence fixing H and H* and leaving countries free to choose subsidies and regulations implements the cooperative outcome. The only source of international spillovers is via prices, and because prices are determined by harvests, the international spillover effect can be internalized with an agreement that restricts harvests.[42]

This approach could also be used to implement an efficient *global* agreement. A globally efficient agreement balances the interests of exporting and importing countries and would mandate that fisheries be maintained at their MSY level. To see this, recall that we are assuming that employment pressures yield a strong depletion potential. Employment and harvesting can be independently controlled, so employment is determined by (32). Regulations can be adjusted to achieve any harvest level up to the MSY level. With

[42] The result that prices are completely determined by harvests H and H* arises because we have implicitly assumed a fully enforced free trade agreement in fish.

employment given, the only reason to harvest below this level is to improve exporters' terms of trade. But this is an inefficient way to transfer income from importers to exporters. So an efficient agreement would fix harvest levels at the MSY levels, in return for concessions from importers (for example via a lump sum transfer).

Proposition 6. Suppose governments put a sufficiently high weight on employment in the fishery such that fisheries in both Home and Foreign have strong depletion potential, and that the MSY constraint does not bind at the joint maximum of the exporting countries (that is, (34) holds).[43] Then

(i) An agreement among exporters to fix harvest levels H and H* can achieve their joint optimum. No restrictions on subsidies are needed. This agreement will improve exporters' terms of trade and harm importers.

(ii) A agreement (covering both exporters and importers) that fixes H and H* at the MSY levels can achieve the global optimum. Restrictions on subsidies are not needed.

Proof: See Appendix I.

The intuition for the result that restrictions on subsidies and domestic regulations are not needed when an agreement on harvest levels is feasible is related to Bagwell and Staiger's (2001a) analysis of the need for restrictions on domestic policy in the WTO. In their framework, countries make market access commitments. Each country is guaranteed some level of access to markets of its trading partners. Trading partners are then free to choose whatever domestic policies they want as long as they adhere to the market access commitments. This works because if the market access commitment is binding, international spillover effects from domestic policies are eliminated (countries have to adjust their policies internally to meet the market access commitment). In our case, because price is determined by H+H*, an agreement to constrain H and H* ensures that any domestic policy changes (subsidies or fisheries regulations) have no international spillover effects.

This suggests that international negotiations on renewable resources might be more

[43] If the MSY constraint does bind then a global agreement is redundant since as we showed earlier, the non-cooperative and globally cooperative equilibria are the same.

successful if they focused on targeting sustainable harvest levels, rather than specific instruments such as subsidies. This would however be a significant expansion of the role of the WTO. Although some trade agreements do have ties to environmental agreements (WTO, 2011), a move to link trade agreements to specific environmental and conservation standards would likely face resistance in part because it would be seen as intrusion into a realm of domestic policy.

7. Extensions

7.1 Subsidies in fish-importing countries

We have focused 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.

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 there is a strong employment motive and fish importing countries are on the downward sloping part of their supply curve, 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 and little or no regulatory capacity than for such an agreement among fish exporters.

If fish importing countries have access to effective fishery regulations and the employment motive is strong enough to generate subsidies, then for fisheries with strong depletion potential, the conditions[44] for the government's choice of N and H□ (given H* and N*) □□□□□□□□□□□□□□

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

and

$$H = H_{MSY}$$

[44] This follows the analysis that led to (29) - (31).

This differs from the case of exporters in that once the employment motive is satisfied, governments always want to produce at the MSY level (assuming the harvesting technology is sufficiently productive to facilitate this). Increased harvesting is always beneficial because it lowers import prices and benefits domestic consumers. With effective resource management, there is no incentive for fish-harvesting importers to support an agreement to reduce subsidies because either it would be ineffective due to adjustments in fishery regulations or it would worsen their terms of trade.

7.2 Individual Transferable Quotas (ITQs)

Sections 4-6 considered outcomes where governments use regulations that increase the costs of fishing. Although this reflects the reality of many fisheries, some fisheries are regulated with ITQs. Under an ITQ system, the government chooses an overall harvest quota H. Individual harvesting quotas are allocated to fishers (either by auction or given away for free to existing fishers) and are freely tradable. In this section, we briefly consider the interaction between fishery subsidies and ITQs.

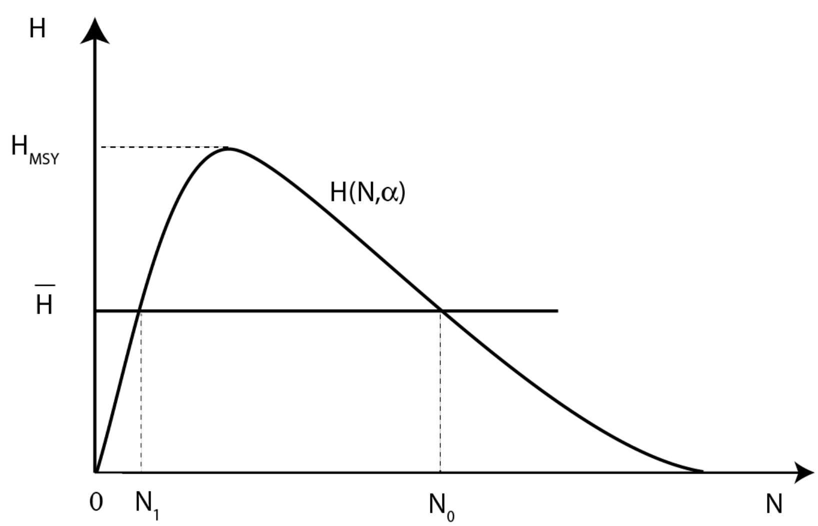

Figure 3.

A key difference between ITQs and the costly regulations of section 4 is that with ITQs the government cannot independently control both employment and the harvest level. With ITQs, the government does not affect the harvesting productivity α, □□□□□□□as we show below, □□□□ H is determined the by quota, N is determined by the market independently of the subsidy. Increases in the subsidy will not affect employment; they will instead be capitalized in quota prices.

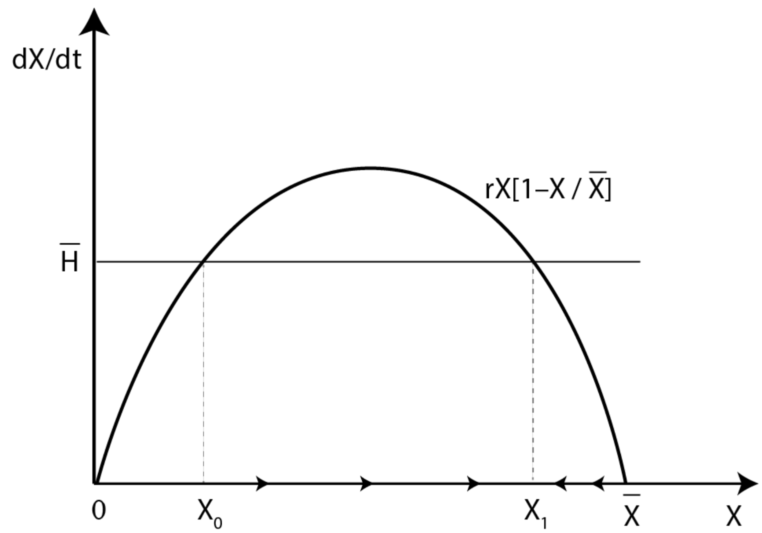

Figure 4.

Moreover, under an ITQ system, the government cannot support any employment level above that which supports the maximum sustainable yield. To see this, consider Figures 3 (which shows sustainable harvest as a function of employment) and 4 (which shows the growth rate of the fish stock as a function of stock size). Suppose employment is initially in steady state equilibrium at a level higher that which supports the MSY harvest, such as N_0 (perhaps supported by a subsidy as in Figure 1). Now suppose the government implements an ITQ with the harvest quota set at $\bar{H}$. Then N_0 will be an unstable equilibrium and employment will fall to N_1. At employment level N_0, there is some steady state fish stock X_0 as illustrated in Figure 4.[45] A random drop in employment will lead to a drop in harvesting which allows the stock to recover, say to $X_0 + \varepsilon$. But at this point the natural growth rate of the stock is greater than the quota-constrained harvest $\bar{H}$, and so, the stock keeps increasing to X_1, which is a stable equilibrium.[46] Note that X_1 corresponds to employment level N_1 in Figure 3. That is, the implementation of the ITQ means that the government is not able to implement its employment target N_0.

[45] This is a well-known diagram from Clark (2010).

[46] A random *increase* in employment would decrease the stock, and would lead to extinction of the stock if the harvest were maintained at $\bar{H}$. However, as the stock drops, harvesting becomes unprofitable for marginal fishers, allowing the stock to recover to X_0.

To see why employment falls, consider the market adjustment to the ITQ. Figure 5 illustrates the ITQ market. Let τ denote the price of a permit to harvest one unit of fish. The supply of harvesting quotas is fixed at $\bar{H}$.

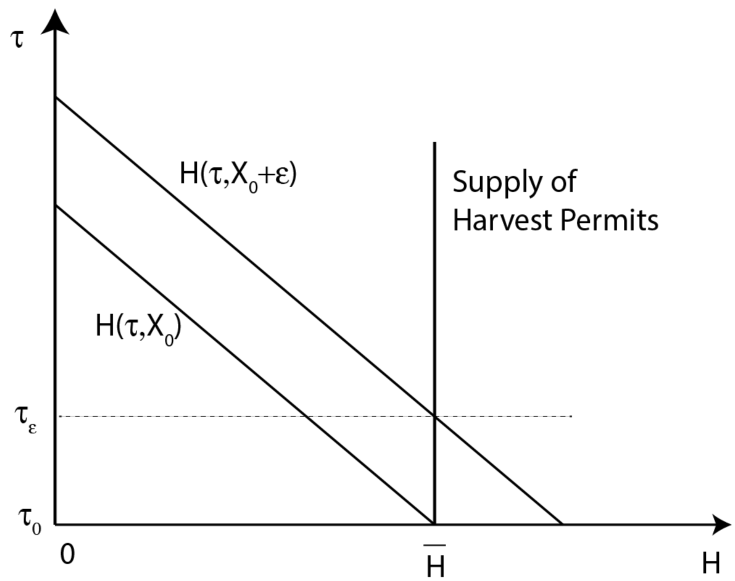

Figure 5.

The demand for permits, $H(\tau, X)$ is decreasing in the permit price and increasing in the fish stock X (a higher stock reduces fishing costs and allows marginal fishers to enter and demand permits). At the initial employment level N_0 in Figure 3, the stock is X_0 (Figure 4) and this yields the permit demand curve $H(\tau, X_0)$ in Figure 5. The initial permit price at the time the ITQ system is introduced is zero ($\tau_0 = 0$), because by assumption the fishery was initially in steady state equilibrium with zero profits for the marginal fisher.

Now consider what happens to permit prices along the adjustment path described above. As the stock X rises, the demand for permits rises because each active fisher is catching more fish. With a fixed supply of permits, the permit price must rise. Marginal fishers are squeezed out. The permit price continues to rise (and employment continues to shrink) as the stock evolves to the new steady state X_1.

Finally note that starting at any stable equilibrium such as N_1 and $\bar{H}$ in Figure 3, an increase in the subsidy will have no effect on employment and simply leads to higher permit prices. A higher subsidy shifts up the demand for permits. With a fixed supply of permits, no entry can be accommodated and so the increase in the permit price will fully offset the effects of the subsidy.

The intuition for this result is straightforward. A key strength of ITQs is that they rationalize a fishery – they lead to rent maximization for a given harvest H. The most efficient harvesters outbid the less efficient harvesters for permits, and so the less efficient fishers leave the industry.[47] The permit price reflects the rent generated by the marginal fisher.

The result suggests that an ITQ system would not be an attractive option for a government that wants to subsidize employment in a fishery to a level beyond that which supports the Maximum Sustained Yield.[48] While ITQs have very attractive efficiency properties, they are used in only a minority of fisheries. Our results here suggest that governments with strong employment motives may be reluctant to adopt ITQs because they lose control over employment in an ITQ system.[49]

7.3. Shared fisheries

We have so far focused on cases where each fish stock is under the jurisdiction of one country. This means that countries are linked only via the terms of trade. Many fish stocks are, however, harvested by more than one country so that countries are linked not only by terms of trade effects, but also by a stock depletion externality - if one country depletes the fish stock, it increases harvesting costs in other countries. Here we briefly consider the implications of shared fish stocks for the incentives to negotiate agreements

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[47] Grafton (1996) reviews the experience of several countries with ITQs and reports that ITQs led to exit of vessels and reductions in employment. Copes and Charles (2004) and Hilborn (2007) also note that employment tends to drop significantly after the introduction of ITQs.

[48] Hilborn (2007, p.155) characterizes controversies over ITQs "*as a conflict in objectives between economic rationalization of fleet size and generation of profits, and those advocates of employment and societal equity.*"

[49] In a more general model where fishers have choices regarding inputs and technology, and where fishers can expand by hiring more labour and capital, a subsidy targeting employment could affect the labour intensity of harvesting in an ITQ regime. However, a subsidy would still have little or no effect on entry because of the cap on harvesting.

on subsidies.

Using the same model as in previous sections, assume now that there is only one fish stock that can be harvested by both Home and Foreign. The growth rate of the stock X depends on both domestic and foreign harvests H and H*. Hence equation (4) becomes:

$$\frac{dX}{dt} = rX\left(1 - \frac{X}{\bar{X}}\right) - H - H^* \qquad (38)$$

The analysis of the model proceeds much the same as in the earlier part of the paper, and so we skip the details. The key issue is that the steady state stock depends on both home and foreign subsidies as well as on the market price. Hence the steady state stock can be written as X = X(p,s,s*), where p is endogenous (and also depends on s and s*).

We now consider the incentives to negotiate. First suppose regulations are exogenous and the only instrument available is a subsidy. When stocks were not shared, we wrote Foreign government welfare as W*(p,s*) in equation (19) because Home's subsidy affected Foreign only via its effect on price. When the stock is shared, Home's subsidy affects Foreign via effects on both price p and the fish stock X. Hence it is convenient to write Foreign government welfare as

$$W^*(p, s^*, X(p, s, s^*)). \qquad (39)$$

Similarly we can write Home government welfare as *W(p,s,X(p,s,s*))*.

Each country chooses its subsidy, treating its rival's subsidy as given. Hence we have:

$$\frac{dW}{ds} = W_p \frac{dp}{ds} + W_s + W_X\left[X_p \frac{dp}{ds} + X_s\right] = 0 \qquad (40)$$

Similarly, dW*/ds* = 0. Let us now consider the effects of a small change in Home's subsidy on the joint welfare of the two countries, starting at the non-cooperative equilibrium. This is the shared-fishery analogue of (23):

$$\left.\frac{d(W+W^*)}{ds}\right|_{dW/ds=0} = W_p^* \frac{dp}{ds} + W_X^* \frac{dX}{ds} \qquad (41)$$

$$(+)(?) \quad (+)(-)$$

Comparing with (23), we see that there is an extra term in the shared fishery case, reflecting the fact that Home's subsidy affects Foreign via two channels – the terms of trade effect and the stock externality effect. The key implication of (41) is that when fisheries are shared there are increased incentives for fish exporting countries to negotiate. If there is a strong employment motive so that countries are on the backward bending part of their fishery supply curves, then dp/ds > 0 and the first term on the right hand side of (41) is positive. An agreement to reduce subsidies would worsen their terms of trade. However this has to be balanced against the second term in (41) which is unambiguously negative. This is the international stock externality effect. Each country overexploits the fish stock (given their employment preferences) because they do not take into account the effects of stock depletion on the other country. If the stock depletion externality is strong relative to the terms of trade effect, then the two countries would gain from an agreement to reduce subsidies.

Suppose now there are two instruments: subsidies and regulations that raise the cost of harvesting. Proposition 4 showed that if market power in fish was not too strong, there would be no incentive to negotiate, because each country would use subsidies to target employment, and regulations to conserve the stock at the maximum sustained yield level. This result no longer holds when the stock is shared. We skip the math here for brevity, but the logic outlined above applies. Because there is a stock externality, neither country will internalize the effects of its regulations on harvesting costs in the rival country. Hence in the non-cooperative equilibrium, regulations will be too weak. This creates an incentive for the two countries to negotiate an agreement to reduce harvesting.

What form should such an agreement take? The same logic discussed in section 6 applies. Rather than trying to negotiate constraints on subsidies and specific regulations, governments could agree on aggregate harvest caps for each country (H and H*), and allow each to choose whatever regulations they prefer to implement the harvest targets.

This is an approach that has been adopted in actual shared fishery agreements.[50]

To see how this can lead to an efficient outcome, note from (38) that the steady state stock can be written as $X = X(H, H^*)$ and recall that the price of fish is determined by aggregate harvest H+H*; that is, $p = p(H + H^*)$. Referring to (39), Foreign government welfare can therefore be written as

$$W^* = W^*\left[p(H+H^*), s^*, X(H,H^*)\right] \tag{42}$$

Home welfare takes the analogous form. Suppose now an agreement sets enforceable targets for H and H*. These targets can be chosen to internalize both the terms of trade effect linkage between countries and the stock externality. With H and H* fixed, the key point is that Foreign welfare is not affected by Home's subsidy: dW*/ds = 0. With harvests fixed by an international agreement, subsidies do not generate international spillover effects. Changes in either country's subsidy have no effect on the other country via either the terms of trade or the stock externality.

We conclude that when there are shared stocks, there is a strong incentive for countries to negotiate an agreement to control harvest levels to internalize the stock externality and terms of trade effects. If this is feasible, there is no need for an agreement to constrain subsidies. Moreover, because harvests are fixed by the agreement, fish importing countries are unaffected by subsidies and hence they also do not have any potential terms of trade benefits from an agreement to constrain subsidies.

8. Conclusion

At first glance, the case for reducing subsidies in fisheries seems compelling. Many fisheries throughout the world have collapsed, and studies such as Worm et al. (2009) suggest that current pressures on fisheries will lead to further collapse. Standard economic analysis highlights stock externalities in fishing and typically calls for taxes (not subsidies) to internalize these externalities. Even if governments are motivated by political motives, the standard analysis of trade agreements (Bagwell and Staiger, 1999)

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[50] See Munro et al. (2004).

points out that regardless of a government's objective function, there is always potential for international agreements to at least partially constrain interventionist policies as long as international spillover effects exist.

In this paper we developed a simple model 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 used by exporters 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 and worsening their terms of trade. This is unlikely to happen for heavily exploited fisheries because subsidies reduce long run output (via stock depletion) and *raise* prices. That is, one exporter's subsidy does not generate negative spillover effects for other exporters and so they would not gain from an agreement to curtail their use. Instead importing countries would gain. This requires a different set of concessions than in the typical case of subsidy negotiations.

Second, 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. A key factor that distinguishes renewable resources from other sectors is that ecological constraints place a cap on sustainable harvests: output is constrained by natural forces. In most other sectors, subsidies lead to overproduction. However because ecological constraints put an upper bound on sustainable production for each fish stock, 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 subsidizing countries to come to an agreement to reduce these subsidies. Each government is acting in accord with its own objectives but there are no international spillover effects to internalize via global negotiations because total output is constrained.

And third, an agreement to reduce subsidies may end up being at least partially undermined unless the WTO were to also get into the business of fisheries management by enforcing harvest quotas. This is because a government that has a political objective to promote employment in the fishery can respond to a commitment 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.

We have focused on fisheries in this paper, but our results have implications for other renewable resource markets. Ultimately our results are driven by two features that make renewable resource markets different than many other markets.

First, if resource management is ineffective, supply curves are backward bending because of stock depletion. An increase in a subsidy can improve an exporting country's terms of trade because increased harvesting can deplete resource stocks, lower long run supply and increase prices. Similar channels exist for other renewable resources. Subsidies for logging and land clearing will reduce the long run flow of sustainable harvests. Subsidies for groundwater use will increase short run agricultural output but reduce long run sustainable production levels. Hence the long run effects of subsidies in renewable resource markets need not result in negative price spillover effects to other exporting countries. In contrast, importing countries suffer long run losses from subsidies via increased prices induced by the fall in sustainable harvesting. This makes the incentive for subsidy negotiations in the renewable resource sector different than many other sectors where typically subsidies benefit importers.

Second, ecological constraints put a cap on sustainable output in the renewable resource sector. In other industries, subsidies lead to over-production and so producers with market power have an incentive to get together to constrain production. In renewable resource markets, the cap on sustainable output acts a bit like a coordination device to restrict production. Countries might want to produce more (and therefore generate negative price spillover effects for other exporters), but ecological constraints prevent this.

A final lesson for other renewable resource markets is that both price and international resource stock spillovers across countries are ultimately driven by resource harvest rates. This suggests international agreements in the renewable resource sector aimed at curbing either price or resource stock spillovers across countries should not mandate restrictions on individual policy instruments (such as subsidies) but instead should focus on harvesting targets. In most industrial sectors, negotiating output targets would be intrusive and inefficient in a dynamic economy. But in the renewable resource sector, the need to ensure sustainability renders negotiations on output targets a natural option.

There is much scope for further work on these issues. We adopt a very simple lobbying model to generate a motive for subsidies. In a more general environment, there may be multiple lobbies - multiple communities in a country may be dependent on the same fishery; and multiple processing sectors may use the harvested output as an input. This can lead to conflicting pressures on government.

We focus on governments with long term horizons which means that they internalize stock externalities when choosing policies. Governments with short term horizons may be less concerned about long run stock depletion and so may have different incentives when it comes to negotiating agreements. We have also extracted from uncertainty. With stochastic resource dynamics, stock depletion leads to some risk of collapse and hence the incentive to subsidize may be dampened, depending on the government's time horizon.

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, international agreements could potentially play a role in helping governments maintain more effective regulation.

REFERENCES

Anderson, A. and A. Rugman (1987) "A fishy business: The abuse of American trade law in the Atlantic groundfish case of 1985-1986", *Canadian Public Policy* 13 (2): 152-64.

Arnason, R. (2012) "Property rights in fisheries: How much can individual transferable quotas accomplish?", *Review of Environmental Economics and Policy*, 6: 217–236.

Bagwell, K. and R.W. Staiger (1999) "An economic theory of GATT", *American Economic Review*, 89:215–248.

Bagwell, K., R.W. Staiger (2001a) "Domestic policies, national sovereignty, and international economic institutions", *Quarterly Journal of Economics*, 116(2): 519-562.

Bagwell, K., R.W. Staiger (2001b) "Strategic trade, competitive industries and agricultural trade disputes", *Economics and Politics*, 13: 113-128.

Bagwell, K. and R.W. Staiger (2012) "The economics of trade agreements in the linear Cournot delocation model", *Journal of International Economic*s, 88(1):32–46.

Bagwell, K. and R.W. Staiger (2015) "Delocation and trade agreements in imperfectly competitive markets", *Research in Economics*, 69: 132-156.

Brander, J.A., B.J. Spencer (1985) "Export subsidies and international market share rivalry", *Journal of International Economics,* 18(1-2): 83-100.

Brander, J.A., M.S. Taylor (1997) "International trade between consumer and conservationist countries", *Resource and Energy Economics*, 19: 267-97.

Brou, D., M. Ruta (2013) "A commitment theory of subsidy agreements", B.E. Journal of Economic Analysis and Policy, 13, 239-270.

Bulte, E. H., Damania, R. (2005) "A note on trade liberalization and common pool resources", *Canadian Journal of Economics*, 38(3): 883-899.

Carvalho, N., S. Rege, M. Fortuna, E. Isidro, and G. Edwards-Jones (2011) "Estimating the impacts of eliminating fisheries subsidies on the small island economy of the Azores", *Ecological Economics*, 70: 1822-1830.

Clark, C.W. (2010) *Mathematical Bioeconomic*s: *The Mathematics of Conservation* (Third Edition), John Wiley, New York.

Clark, C.W., G.R. Munro, and U.R. Sumaila (2005) "Subsidies, buybacks, and sustainable fisheries", *Journal of Environmental Economics and Management*, 50: 47-58.

Contreras-Hermosilla, A. (2000) "The underlying causes of forest decline", No. CIFOR Occasional Paper no. 30, p. 25p, CIFOR, Bogor, Indonesia.

Copeland, B. R. (1990) "Strategic enhancement and destruction of fisheries and the environment in the presence of international externalities', *Journal of Environmental Economics and Management*", 19(3): 212-226.

Copes, P., and A. Charles (2004) "Socioeconomics of individual transferable quotas and community" *Agricultural and Resource Economics Review*, 33: 171-181.

Costello, C., S. Gaines and J. Lynham (2008) "Can catch shares prevent fisheries collapse?" *Science*. 321: 1678-1681.

FAO (2011), Review of the State of World Marine Fishery Resources, FAO Fisheries and Aquaculture Technical Paper 569, Rome.

Fisheries Bridges (2017) "WTO negotiators debate scope, application of potential fish subsidies deal", ICTSD, 21(22), 22 June 2017.

Goldberg, P.K. and G. Maggi (1999) "Protection for sale: An empirical investigation", *American Economic Review,* 89: 1135-55.

Grafton, R. Q. (1996) "Individual transferable quotas: theory and practice", *Reviews in Fish Biology and Fisheries*, 6(1): 5-20.

Grainger, C., C. Costello (2016) "Distributional effects of the transition to property rights in a common pool resource", *Marine Resource Economics*, 31(1): 1-26.

Grossman, G. and E. Helpman (1994) "Protection for sale", *American Economic Review*, 84: 833-50.

Hilborn, R. (2007) "Defining success in fisheries and conflicts in objectives", *Marine Policy*, 31: 153-158.

Homans, F.R., J.E. Wilen, (1997) "A model of regulated open access resource use", *Journal of Environmental Economics and Management*, 32(1):1-21.

Jinji, N. (2012) "Fisheries subsidies and management in open economies", *Marine Resource Economics*, 27: 25-41.

Kronbak, L.G, Lindroos, M. (2006) "An enforcement-coalition model: fishermen and authorities forming coalitions", *Environmental and Resource Economics*, 35(3): 169-194.

Maggi, G., A. Rodriguez-Clare (1998) "The value of trade agreements in the presence of political pressures", *Journal of Political Economy*, 106(3): 574-601.

Mesterton-Gibbons, M. (1993) "Game-theoretic resource modeling", *Natural Resource Modeling*, 7(2): 93-147.

Milazzo, M. (1998) "Subsidies in world fisheries: a reexamination", World Bank Technical Paper No.406, Washington, DC: The World Bank.

Munro, G. R. (1979) "The optimal management of transboundary renewable resources", *Canadian Journal of Economics,* 355-376.

Munro, Gordon R., (2007) "Internationally shared fish stocks, the high seas, and property rights in fisheries", *Marine Resource Economics,* 425-443.

Munro, G. R., A. van Houtte, and R.Willman (2004) *The conservation and management of shared fish stocks: legal and economic aspects.* Food and Agriculture Organization of The United Nations, Rome.

OECD (2003), Environmentally Harmful Subsidies: Policy Issues and Challenges, Paris, OECD Publishing.

OECD, (2006) Financial Support to Fisheries: Implications for Sustainable Development, Paris, OECD Publishing.

Pauly, D., V. Christensen, S. Guénette, T. J. Pitcher, U. R. Sumaila, C. J. Walters, R. Watson, and D. Zeller (2002) "Towards sustainability in world fisheries", *Nature*, 418(6898): 689-695.

Pintassilgo, P., Finus, M., Lindroos, M., & Munro, G. (2010) "Stability and success of regional fisheries management organizations", *Environmental and Resource Economics*, 46(3): 377-402.

Pintassilgo, P., Lindroos, M. (2008) "Coalition formation in straddling stock fisheries: a partition function approach", *International Game Theory Review,* 10.03: 303-317.

Porter, G. (1997) "Natural resource subsidies, trade and environment: the cases of forests and fisheries", *Journal of Environment and Development*, *6*(3).

Porter, G. (2003). Subsidies and the Environment: an Overview of the State of Knowledge. In *OECD Workshop on Environmentally Harmful Subsidies,* Paris (p. 7-8).

Quinn, J., G. Ruseski (2001) "Effort subsidies and entry deterrence in transboundary fisheries", *Natural Resource Modeling*, 14(3): 369-389.

Repetto, R. (1988) "The forest for the trees", *Government Policies and the Misuse of Forest Resources*, 43-51.

Rus, H. A., (2012) "Transboundary marine resources and trading neighbours", *Environmental and Resource Economics*, 53(2): 159-184.

Ruseski, G., (1998) "International fish wars: the strategic roles for fleet licensing and effort subsidies", *Journal of Environmental Economics and Managemen*t, 36: 70-88.

Sakai, Y. (2017) "Subsidies, fisheries management, and stock depletion", *Land Economics*, 93(1), 165-178.

Schaefer, M.B. (1957) “Some considerations of Population dynamics and economics in relation to the management of marine fisheries”, *Journal of Fisheries Research Board of Canada*, 14:669-681.

Schrank, W. E., N. Roy, R. Ommer,and B. Skoda (1992) "An inshore fishery: a commercially viable industry or an employer of last resort", *Ocean Development & International Law*, 23(4) : 335-367.

Schuhbauer, A., Chuenpagdee, R., Cheung, W. W., Greer, K., & Sumaila, U. R. (2017) "How subsidies affect the economic viability of small-scale fisheries", *Marine Policy*, 82, 114-121.

Sumaila, U.R., D.Pauly (2006) "Catching more bait: A bottom-up re-estimation of global fisheries subsidies", Fisheries Centre, University of British Columbia, Fisheries Centre Research Reports 14.

Sumaila, U. R., A. Khan, R. Watson, G. Munro, D. Zeller, N. Baron, and D. Pauly (2007) "The World Trade Organization and global fisheries sustainability", *Fisheries Research*, 88: 1-4.

Sumaila, U. R., A. Khan, R. Watson, L. The, R. Watson, P. Tyedmers, and D. Pauly (2010a) "Subsidies to high seas bottom trawl fleets and the sustainability of deep-sea demersal fish stocks", *Marine Policy*, 34: 495-497.

Sumaila, U. R., Khan, A. S., Dyck, A. J., Watson, R., Munro, G., Tydemers, P., & Pauly, D. (2010b) "A bottom-up re-estimation of global fisheries subsidies", *Journal of Bioeconomics*, 12(3), 201-225.

Sumaila, U. R., Lam, V., Le Manach, F., Swartz, W., & Pauly, D. (2016) "Global fisheries subsidies: An updated estimate", *Marine Policy*, 69, 189-193.

Takarada, Y., W. Dong and T. Ogawa (2015) "Shared renewable resources and gains from trade under technology standards," mimeo, Nanzan University.

Young, M., (2009) "Fragmentation or interaction: the WTO, fisheries subsidies, and international law", *World Trade Review*, 8(4): 477-515.

World Bank, (2009) "The sunken billions: The economic justification for fisheries reform", The World Bank, Washington.

Worm, B. et al., (2009) "Rebuilding global fisheries", *Science*, 325: 578-585.

WTO (2011), *World Trade Report*, World Trade Organization.

Appendix I: Proofs of Propositions

Proof of Proposition 1.

Proofs of (iii) and the price response part of (ii) are in the text. Here we prove (i) and show that the subsidy can be high enough to put the harvesting countries on the backward bending part of their supply curves. Each government maximizes an objective of the form (14). Note that V(p) and surplus Π are bounded below by 0, and both approach zero as the fishery is depleted. The Home government's problem can then be written as

$$\max_{s}\left\{\varphi(N)+\frac{V(P)+\Pi}{\lambda}\right\}$$

As the weight λ on political motives gets sufficiently large, the second term in the objective approaches zero and solution (regardless of the level of the foreign subsidy) is to choose a subsidy to make N as large as possible. Referring to Figure 1, this means that N approaches $A^{-1}(r/\alpha)$ as λ approaches infinity. Hence there exists $\underline{\lambda}$ such that for $\lambda > \underline{\lambda}$, Home will subsidize its fishery and this subsidy will be high enough that the country will be on the backward bending part of its fish supply curve. The same argument works for the foreign country.

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, if there is an interior solution we have:

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

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, there exists a feasible α level to support the level of employment chosen by the government.

Proof of Proposition 3.

Joint government welfare is

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

A planner chooses H,H*, N and N* to maximize joint welfare subject to the MSY constraints. The first order 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 (i.e. at the MSY levels) 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.

Proof of Proposition 5.

We need to show how the government's choice of H (and hence regulation) responds to a fall in subsidies when the MSY constraint binds. We use Figure 2. Using the right hand side of (36), the effect of a *fall* in the subsidy on the MC^H curve is given by

$$-\frac{\partial MC^H}{\partial s}\bigg|_{H=H_0} = \underset{(?)}{\lambda} \underset{(+)}{N_H} \underset{(-)}{N_s \varphi''} \qquad \text{(A1.1)}$$

The sign is determined by N_H; that is, by whether or not an increase in H raises or lowers employment. From (35),

$$N_H = \frac{d\left[p^d(H+H^*)H\right]/dH}{(w-s)B'(N)}$$

where $B(N) \equiv A(N)/a(N)$ and $B'(N)>0$. Hence employment can be increased via a change in H if total revenue rises as H changes.

When (30) holds (that is, when the MSY constraint binds) the effect of a change in H on total revenue is

$$\frac{d[p^D(H+H^*)H]}{dH} = p^D + p_H^D H \qquad \text{(A1.2)}$$

And when (30) holds, we have $p^D + p_H^D H > p_H^D D$ since E = H - D where D is domestic consumption. If all fish are exported, then D = 0 and so (A1.2) is positive. Total revenue rises if H rises. But if D > 0 and H is sufficiently large then (A1.2) could be negative.

There are three possibilities. If an increase in H raises total revenue (demand is locally elastic), then a marginal increase in H would raise employment ($N_H > 0$). 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 increase in H would reduce employment (i.e. $N_H < 0$) and so MC^H shifts *up* when the subsidy is reduce. 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.

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.

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. 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).

Proof of Proposition 6.

(i) Proof is in the text.

(ii) The globally efficient solution solves

$$\max_{\{N,N^*,H,H^*\}}\left\{V(p)+pH+\lambda\varphi(N)-wN+V^*(p)+pH^*+\lambda^*\varphi^*(N^*)-w^*N^*+V^{ROW}(p)\right\}$$

Let H^W = H+H* and recall p = p(H+H*).

It is convenient to first solve for N, N* and H^W and then consider how H^W should be allocated across Home and Foreign. Our problem then becomes

$$\max_{\{N,N^*,H^W\}}\left\{V(p)+V^*(p)+V^{ROW}(p)+pH^w+\lambda\varphi(N)-wN+\lambda^*\varphi^*(N^*)-w^*N^*\right\}$$

The first order conditions for choice of N and N* are:

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

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

The effect of a change in H^W on global (world) welfare (W^W) is

$$\frac{dW^W}{dH^W} = \left[V_p + V_p^* + V_p^{ROW}\right] p_{H^w} + H^W p_{H^w} + p$$

But using Roy's identity (V_p = –D, where D is Home demand; etc.) and global market clearing (the sum of demands across the three regions must equal world production H^w), we have

$$V_p + V_p^* + V_p^{ROW} + H^W = 0$$

and so

$$\frac{dW^G}{dH^W} = p(H^w)$$

This just says that the marginal benefit of an increase in global harvest is given by global demand. So for any H^w at which $p(H^W) > 0$, an increase in H^W raises global welfare. The reason for this is (1) because the first order conditions for N and N* fix employment, the opportunity cost of relaxing regulations to increase harvest is zero and (2) any terms of trade effects cancel out because they are a pure redistribution of income. Hence the solution is to make H^w as large as possible (on a sustained basis). Hence the solution is to set H and H* at their MSY levels. Finally note that when H and H* are fixed, Home and Foreign's optimal choice of subsidies and regulations will implement the solutions for employment found above. [With H fixed, Home's government's problem reduces to choosing N to maximize $\lambda\varphi(N) - wN$]. Hence no constraints on subsidies and regulations are needed.

Appendix II: Transitional Dynamics

In this appendix we illustrate the transition to a new steady state when Home and Foreign agree to cut subsidies. We suppose that both countries are initially in steady state equilibrium in the region where their supply curves are backward bending (because this is the most interesting and relevant case). For simplicity we assume that the countries are symmetric.

It is easiest to illustrate the transitional dynamics using Figure A1. Let G(X) denote the natural growth of the stock; that is from (4):

$$G(X) \equiv rX\left(1 - \frac{X}{\bar{X}}\right) \qquad \text{(AII.1)}$$

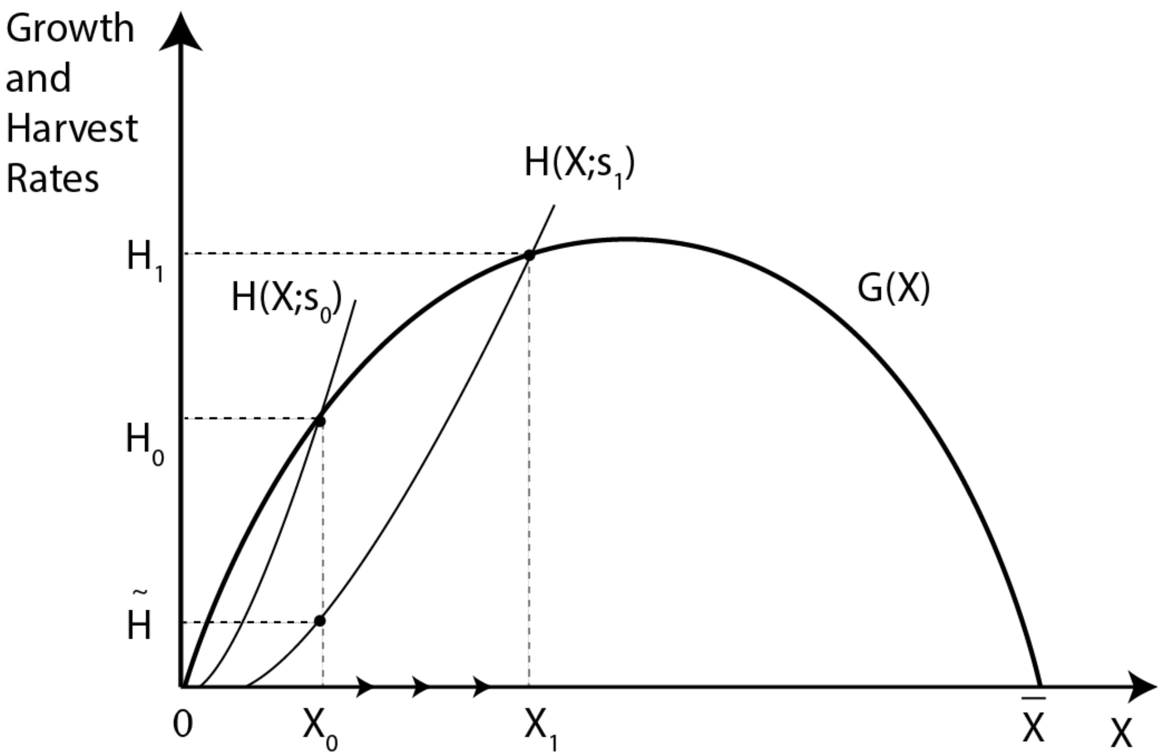

Figure A1.

The curves H(X;s_i) are the equilibrium harvest at any point in time given that stock is X and the subsidy is s_i. We derive H(X;s_i) below and show it is upward sloping. Note that there is a minimum stock size needed to make harvesting profitable for the most productive fisher (this requires $p(0)\alpha a(0)X \geq w - s$). Hence assuming there is some choke price for demand, the harvest curves intersect the horizontal axis to the right of the origin.

At the original subsidy s_0, the steady state stock is X_0 and harvest is H_0. The impact effect of a reduction in the subsidy to s_1 is to induce exit from the fishery and so the harvest immediately drops to $\tilde{H}$. Because the harvest is now below the natural growth rate G(X), the stock starts growing and gradually moves towards the new steady state stock X_1. As the stock increases, the harvest starts increasing and gradually evolves towards H_1. We illustrate the transition paths for H and X in Figure A2.

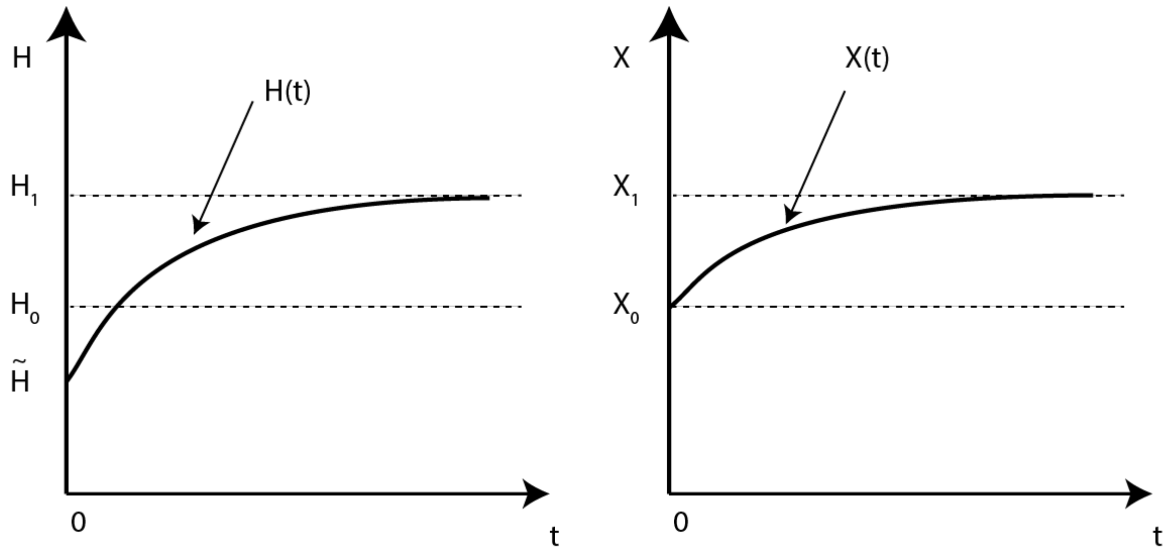

Figure A2. Transitional dynamics for Harvest rates H(t) and the fish stock X(t)

Price initially drops on impact because the short run effect of the fall in subsidies is to reduce supply. In the long run as fish stocks recover and harvest increases, the price of fish gradually falls to its new steady state level which is below the initial price.

The path of employment N is more complex. Recall that employment is given by (35). Define domestic revenue from the harvest sector as

$$R(H, H^*) = p^D(H + H^*)H \tag{AII.2}$$

Then we can write the employment condition (35) as

$$\frac{A(N)}{a(N)} = \frac{R(H, H^*)}{w - s} \tag{AII.3}$$

The left hand side is increasing in N. And recall we are assuming symmetry so that H = H*. Employment will drop discretely when the subsidy is reduced. Since H is rising over time as the economy approaches the new steady state, then from (AII.3), the path of N depends on whether total domestic revenue R from harvesting rises or falls as H and H* rise. This depends on the demand elasticity. Using H = H*, one can show that revenue rises as H and H* rise if the demand elasticity $\varepsilon > 1$. Hence after its initial drop, employment may rise or fall or even be non-monotonic during the transition to its new steady state level (which we know from (8) must be lower than it was initially because of the reduced subsidy). In Figure A3 we illustrate the case where the demand is relatively elastic and employment rises during the transition.

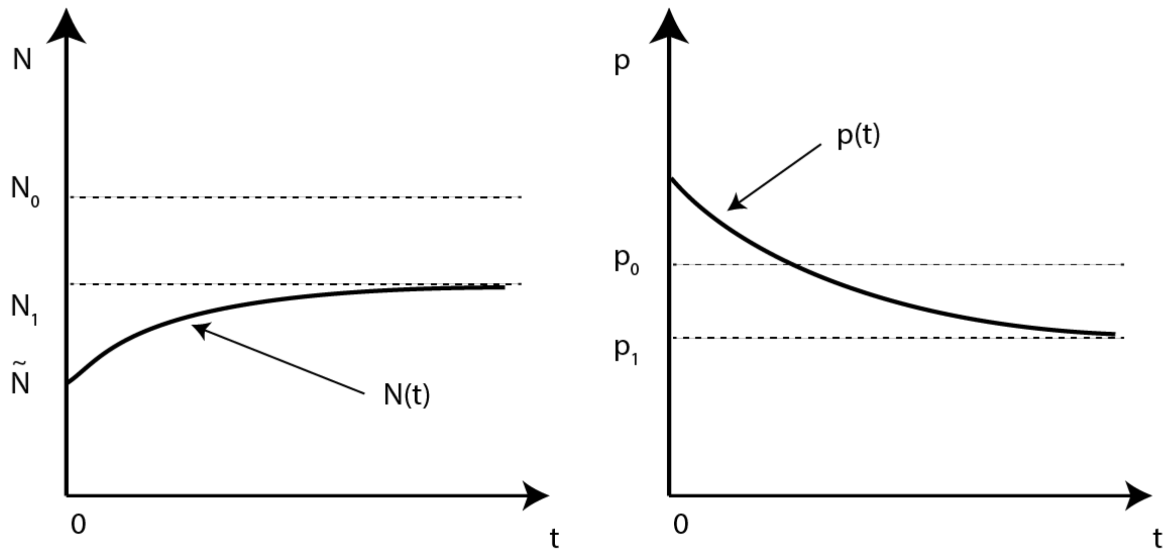

Figure A3. Transitional dynamics for employment N(t) and prices p(t)

Perhaps the most interesting result from the transition is that the short and long run effects of the subsidy reduction on the price differ. In the short run, we obtain the standard result that s subsidy reduces supply and pushes up the price (short run supply curves slope upward). As stocks recover, supply increases and price falls, and in the steady state the reduction in subsidies has lead to a fall in the long run price (this reflects the backward bending long run supply curves). In our model we have focused on the case where discount rates approach zero and governments choose policies based on long run outcomes. The transition dynamics suggest that there could be interesting strategic interactions between countries and between governments and lobby groups if their time horizons differ. However full analysis of these issues would require a differential game and we leave this for future work.

Derivation of the harvest curve H(X;s)

Finally we verify that the Harvest function H(X;s) illustrated in Figure A1 is upward sloping. The aggregate harvest function (3) and the free entry condition (7) implicitly jointly determine H and N as functions of X and s. We solve for dH/dX.

It is useful to define

$$B(N) \equiv \frac{A(N)}{a(N)} \tag{AII.4}$$

Then we can write (AII.3) as

$$B(N) = \frac{R(H, H^*)}{w-s} \tag{AII.5}$$

We can write the free entry condition (7) as

$$\alpha a(N) X = \frac{w-s}{p} \tag{AII.6}$$

Totally differentiating the aggregate harvest function (3) and using (AII.6) yields

$$dH = \frac{w-s}{p} dN + \alpha A(N) dX \tag{AII.7}$$

Totally differentiating (AII.5) yields

$$dN = \frac{R_H dH + R_{H^*} dH^*}{B'(N)(w-s)} \tag{AII.8}$$

Substitute (AII.8) into (AII.7) and use symmetry across countries (dH = dH*) and rearrange to obtain:

$$\frac{dH}{dX} = \frac{\alpha A(N)}{1 - \frac{R_H + R_{H^*}}{pB'(N)}}$$

Using the definition of B and R, we can simplify to

$$\frac{dH}{dX} = -\frac{\alpha A(N) p B'(N)}{pa' A / a^2 + 2p_H H} > 0$$

where the inequality follows because a'(N) < 0 and $p_H < 0$.

Appendix III: Subsidy Agreements when the MSY Constraint Does Not Bind

If fish are sufficiently abundant, then the MSY cap will not bind and the potential for a subsidy agreement is much like that for other commodities. This arises when (31) and (34) hold. Exporters produce excessively in the non-cooperative equilibrium because they do not internalize terms of trade effects for other exporters.

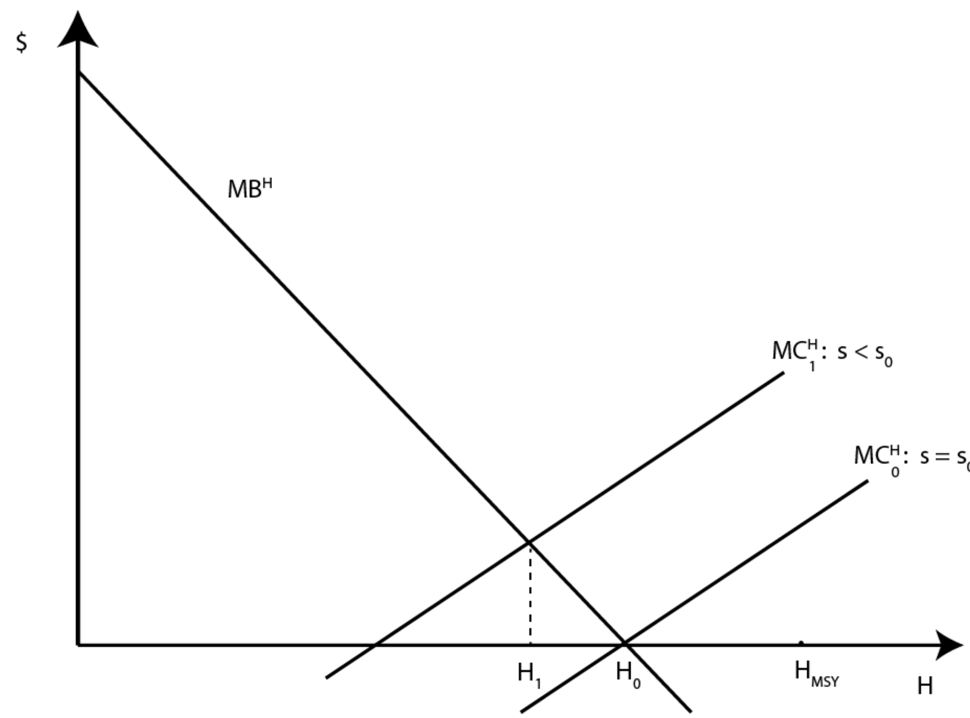

Figure A4. Strong Market Power: Exogenous reduction in the subsidy reduces H

We illustrate this case in Figure A4. 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, given H*. This has no effect on MB^H, but causes an upward shift in MC^H. To see why, recall the proof of Prop. 5. A fall in the subsidy shifts up MC^H if aggregate revenue from harvesting falls when H rises. The change in revenue from an increase in H is given by (A1.2). When (31) holds in the non-cooperative equilibrium we have

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

since E = H - D where recall that D is domestic consumption. That is, when (31) holds, market power is strong and so a increase in H would decrease total revenue from the fishery. This means that a reduction in harvest will be needed to increase employment (since it boosts revenue) and so MC^H shifts up (given the new lower s, the initial level of harvest is too high), as we have illustrated in Fig. A4. This yields H_1 as the best response to H*. That is, Home's best response curve shifts in.

We conclude 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 (so that the MSY constraint does not bind), there is an incentive for the two exporting countries to negotiate an agreement to reduce subsidies. Although governments will engage in some policy substitution (regulations will be adjusted in response to the change in the subsidy, this will only dampen but not eliminate the effect of a reduction in the subsidy.

This case only arises when market power in the fishery is very strong. That is, fish must be sufficiently abundant and demand sufficiently inelastic that exporters would collectively gain from keeping harvest below the MSY level.