A STACKELBERG ANALYSIS OF THE POTENTIAL FOR COOPERATION IN STRADDLING STOCK FISHERIES

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ABSTRACT

To ensure the long-term conservation and sustainable use of straddling fish stocks, the 1995 United Nations Fish Stock Agreement calls for the establishment of regional fisheries management organizations to manage such stocks. This paper studies the potential for cooperation in straddling stock fisheries when the cooperative coalition of countries acts as a Stackelberg leader against the remaining singleton countries. It is demonstrated that an increase in the cooperation level leads to an increase not only in the steady-state fish stock, but also in the total rent of the fishery. Further, the outlook for cooperation is better within the Stackelberg game, where the cooperative coalition acts as a leader, than in the Cournot game. At the stable equilibrium of a Stackelberg game, not only is the steady-state fish stock higher, but also the total resource rent, participants' rent and non-participants' rent are higher than those of the Cournot–Nash stable equilibrium. The new-entrant issue is also a problem for the conservation of the fish stock in the Stackelberg game. According to the present research, the prospects of cooperation in utilizing a straddling fish stock are not unlikely if the cooperative coalition acts as a leader. This is an important implication for policymakers when discussing an agreement for establishing a regional fisheries management organization (RFMO) to manage a straddling fish stock.

Keywords: Non-cooperative approach, regional fisheries management organization, shared fisheries, stable coalition, Stackelberg game.

INTRODUCTION

Internationally shared fish resources account for as much as one-third of the world marine capture fish harvest (Munro, Van Houtte and Willmann 2004). The FAO (2003) has declared that the effective management of these resources represents one of the great challenges on the way to achieving sustainable fisheries. This paper focuses on shared resources with several interested parties. The management of the marine resources in the South China Sea (SCS), where the resources are harvested by about ten countries, is one example to which this analysis may be most relevant. The North-East Atlantic (NEA), fished by even more countries, is another example.[1] In both cases, several migratory species are seasonally more or less available for fishermen in different locations and countries. There is, however, one important difference between these two oceans. In the NEA case, 200 miles of internationally recognized exclusive economic zones (EEZs) have been established along almost all the coasts. This still leaves some important fishable areas in international water between two or more EEZs. In the SCS, however, few EEZs are so far internationally recognized. Thus, the establishment of international arrangements that limit the international race for fish is still needed in some important fishing areas of the world. This paper is a theoretical contribution to the management of straddling fish stocks – one type of shared fish stocks (see Bjorndal and Munro 2007) – which cross the EEZ boundaries into the adjacent high seas where the resources are subject to exploitation by so-called distant-water states.

The exploitation of a fish stock shared by a limited number of agents involves strategic choices. The theory of fisheries games before 1995 concerned cases of just two agents (see e.g. Munro (1979) for an early contribution, Kaitala (1986), Munro (1991), Sumaila (1999) and Lindroos *et al.* (2007) for reviews and Kaitala and Pohjola (1988) and Armstrong and Flaaten (1991) for applications). However, many important stocks in the EEZs are shared by two or more coastal states and the straddling of some fish stocks outside the EEZs means they are accessible by fleets of any nationality (Hannesson 1997). Kaitala and Munro (1993), Kaitala and Munro (1995), Kaitala and Lindroos (1998), Bjorndal et al. (2000), Lindroos (2004) and Bjorndal and Munro (2007) have considered the management issues of a shared fish stock when the number of agents involved is greater than two.

The utilization of a shared fish stock is currently based on the legal frameworks proposed by the 1982 United Nations Convention on the Law of the Sea (UN 1982) – hereafter called the LOS – and the 1995 United Nations Fish Stock Agreement on the Conservation and Management of Straddling and Highly Migratory Fish Stocks (UN 1995) – hereafter called the UNFSA. At the heart of the UNFSA lies the establishment of Regional Fishery Management Organizations (RFMOs) to manage straddling and highly migratory fish stocks. These fish stocks are simply referred to as straddling fish stocks (see also Bjorndal and Munro 2007). According to Article 8 of the UNFSA, only member states of RFMOs and states that apply the fishing restrictions adopted by them shall have access to the regulated fishery resources. However, the UNFSA is binding only upon those states that are party to it. As of 25 September 2008, there are 71 states party to the UNFSA (UN 2008). Munro (2003) argued that, under the UNFSA, in the case of a straddling stock, a state or entity that is not a member of the RFMO, found to be fishing in the high seas governed by the RFMO, would be deemed to be engaged not in illegal fishing but rather in unregulated fishing; thus, he claimed that unregulated fishing can be seen as another form of free riding. Moreover, the incidence of illegal, unreported and unregulated (IUU) fishing is pervasive over many parts of the world (FAO 2001). Lodge *et al.* (2007) suggested that the RFMO members should recognize the grave threat to the stability of the cooperative regime posed by IUU fishing and work vigorously towards the suppression and elimination of such fishing.

For the reasons discussed above, it is important for the understanding of RFMO management of a straddling fish stock that this fishery is modelled with the equilibrium concept of a self-enforcing or stable agreement. A stable agreement made between parties, to our best knowledge first proposed by D'Aspremont *et al.* (1983), and later coined by Barrett (1994, 2003) for use in his analysis of international environmental relations, is defined as a single coalition from which no member wishes to withdraw (the cooperative coalition is internally stable) and no non-member wishes to join (the cooperative coalition is externally stable). For the purposes of the analyses of RFMOs, both cooperative and non-cooperative game theories are needed.[2]

To use the non-cooperative approach for examining the potential cooperation in utilizing a straddling fish stock under the legal framework of the LOS and the UNFSA, this paper considers a single coalition (including participants of the RFMO) through which members coordinate their strategies and assume that all non-participant countries behave as singletons. Finus (2001) demonstrated that the Cournot and Stackelberg games are two extreme modes of the game between the cooperative coalition and the remaining singletons. The Cournot game is a model in which the cooperative coalition and the singletons simultaneously maximize their payoffs, taking the effort levels of the others as given. In the Stackelberg game, the cooperative coalition takes into account its ability to influence the singletons' output by choosing its own fishing effort with endogenous effort levels of the singletons. This means that the cooperative coalition acts as a leader of the game or it has a strategic advantage.

The literature examining the cooperative and non-cooperative consequences of a shared fishery by Cournot and Stackelberg games adopts both dynamic and static approaches. Levhari and Mirman (1980) compared results of the two games in the case of two countries and two periods. Benchekroun and Long (2002) argued that migratory fish that travel along the coastline of several nations are subject to sequential fishing and applied a Stackelberg game for a differential game of two agents. Naito and Polasky (1997) also employed the Stackelberg assumption with a two-period dynamic game model to investigate the leading role of a coastal country in utilizing a migratory fish stock when distant-water fishing nations are assumed to act as singletons. Hannesson (1997) used repeated games, with a Cournot assumption in the punishment period, to study factors affecting the stable grand coalition of a shared fishery. In contrast, Mesterton-Gibbons (1993) was the first to give an analysis of static non-cooperative fisheries games with a Cournot assumption. Ruseski (1998) adopted the static approach in a Cournot game in the case of two agents to examine the consequences of direct fishing subsidies on a shared fishery. Kronbak and Lindroos (2006) also employed the static game to examine fishermen and authorities forming coalitions. Pintassilgo and Lindroos (2006) used the static approach with a Cournot assumption of choosing fishing effort among coalitions to examine the cooperative coalition formation when there are two or more countries involved in straddling stock fisheries. Long (2009) adopted the same method used by Pintassilgo and Lindroos (2006) to examine the potential of cooperation in straddling stock fisheries if an RFMO forms with an endogenous minimum participation level. Pintassilgo *et al.* (2008) extend the analysis of Pintassilgo and Lindroos (2006) by consideration of the asymmetry of harvesting costs. Kaitala and Lindroos (2007) argued that the advantage of static over dynamic games is that analytical results are easier to derive and interpret. In addition, since the static approach provides a good long-term prediction, it is consistent with the UNFSA's aim of establishing an RFMO to sustain the long-term stability of shared fish stocks (Long 2009).

To ensure the long-term conservation and sustainable use of straddling fish stocks, the UNFSA calls for the establishment of RFMOs to manage these marine fish stocks. Using the static Cournot game combined with the classical Gordon–Schaefer model for homogenous fishing countries, Pintassilgo and Lindroos (2006) have, however, demonstrated that a non-cooperative solution is the inevitable outcome when the number of agents is more than two and the grand coalition is a Nash stable equilibrium outcome only if there are two countries sharing a fish stock. Their result raises the question of whether the establishment of RFMOs to manage straddling stock fisheries under the UNFSA is stable and successful. Pintassilgo *et al.* (2008) have shown that the success of RFMOs is related to the level and asymmetry of harvesting costs in the static Cournot game. To investigate the potential for cooperation in straddling stock fisheries, this paper, in the other way, assumes that an RFMO for managing a straddling stock fishery is sophisticated and acts as a Stackelberg leader, and that the singletons are naïve and act as the Stackelberg followers. Hence, a Stackelberg game, the other extreme mode of the game between the cooperative coalition and the remaining singletons, is adopted in this study. Clearly, a comparison of this model and the one generated by a Cournot game may give some important insights for policymakers.

This paper uses a static Stackelberg game combined with the classical Gordon–Schaefer model to examine the potential of cooperation in utilizing a straddling fish stock. The findings are also compared with the alternative mode of the strategic interaction, the Cournot game, shown in Pintassilgo and Lindroos (2006) and Long (2009). In this study, we show that (i) an increase in the level of cooperation leads to an increase not only in the steady-state fish stock, but also in the total resource rent of the fishery; (ii) the outlook for cooperation is better within the Stackelberg game, where the coalition acts as a leader, than in the Cournot game; (iii) at the stable equilibrium in a Stackelberg game, not only is the steady-state fish stock higher, but also the total resource rent of the fishery, participants' rent and non-participants' rent are higher than those of the Cournot–Nash stable equilibrium; (iv) the new-entrant issue is a problem for the conservation of this fish stock in the Stackelberg game; (v) self-financed transfers with commitments of the initial stable coalition will increase the level of stable cooperation.

MODEL AND ANALYSIS

We assume that *N* countries exploit a straddling fish stock, $C = \{1,\ldots,N\}$. The harvest function, with equal catchability coefficient *q*, is the same across countries. Suppose that each country uses fishing effort $e_i \geq 0, i \in C$. For simplicity, the classic Gordon–Schaefer bio-economic model is used (see Clark 1976):

$$\frac{dx}{dt} = G(x) - H,$$

where G is the population renewal function and H is harvesting summed across all the countries. We assume that $G(x) = rx(1-\frac{x}{K})$ and $H = \sum_{i=1}^{N} h_i = qx\sum_{i=1}^{N} e_i$, where G is the logistic growth function, h_i is the harvest of player i, K is the carrying capacity for a fish stock and r is the intrinsic growth rate. The steady-state relation between fishing effort and stock growth is given by $G(x) = H$, or

$$rx(1-\frac{x}{K}) = qx\sum_{i=1}^{N} e_i. \tag{1}$$

We assume a linear cost function for each country. To be comparable with Pintassilgo and Lindroos (2006) and Long (2009), the unit price of fish p and unit effort cost c are assumed to be constant and equal for every country. Therefore, the welfare of country i, π_i, resource rent, the difference between revenue and cost of fishing are given as:

$$\pi_i = pqe_i x - ce_i. \tag{2}$$

To proceed, assume that when a cooperative coalition is established, its by-laws allow any of the N players to choose either to be a member or a non-member of the cooperative coalition. In addition, assume that the coalition's participants fully comply with the terms of agreement. Next, suppose that $s \in [2/N, 3/N, ..., (N-1)/N]$ is the fraction of countries that join the cooperative coalition – hereafter called the cooperation level. Ns, an integer, is the number of countries that form a coalition while $N(1-s)$ is the number of singletons that stay outside the cooperative coalition. Thus, the cooperative coalition includes at least two agents. The partial cooperative case deals with a cooperation level in the range from $2/N$ to $(N-1)/N$. The total fishing effort of the cooperative coalition is E_p, while each participant of the cooperative coalition uses e_p, such that $E_p = Nse_p$. Each non-participant (singleton) uses e_{np}, yielding a total fishing effort level of all the singletons $E_{np} = N(1-s)e_{np}$. The total fishing effort of the fishery is $E = E_p + E_{np}$.

Stackelberg leadership of the cooperative coalition assumes that, when choosing its cooperative fishing effort, the cooperative coalition will take the reaction of the singletons into account (Finus 2001). This means that the cooperative coalition chooses its fishing effort with endogenous effort levels of singletons (see e.g. Barrett 1994). In other words, the cooperative coalition acts as a leader of the game or it has a strategic advantage (Finus 2001).

To be comparable with Pintassilgo and Lindroos (2006) and Long (2009), assume that each singleton chooses its fishing effort to maximize its resource rent,[3] taking the fishing effort levels of the remaining singletons and the cooperative coalition as given:

$$\max_{\{e_{np}\}} \ \pi_{np} = pqe_{np}x - ce_{np}$$

$$\text{subject to } qx\left[e_{np} + [N(1-s)-1]\bar{e}_{np} + \bar{E}_p\right] = rx(1 - x/K), \tag{3}$$

where $\bar{e}_{np}$ and $\bar{E}_p$ are the fishing effort of each remaining singleton and the cooperative coalition, respectively, and are given. Next, the cooperative coalition chooses its fishing effort level by maximizing the collective rent while taking into account the behaviour of singletons. That is, the cooperative coalition chooses $E_p = Nse_p$ by solving the following maximization problem:

$$\max_{\{E_p\}} \ P_p = pqE_p x - cE_p$$

$$\text{subject to } xq\left[N(1-s)e_{np} + E_p\right] = rx(1 - x/K). \tag{4}$$

At equilibrium, $\overline{e}_{np} = e_{np}$ and $\overline{E}_p = E_p$. Solving (3) and (4), the fishing effort of a participant, a non-participant and the fishery are, respectively (see Annex 0 for detail):

$$e_p = \frac{r(1-b)}{2qNs},\ e_{np} = \frac{r(1-b)}{2q\left[N(1-s)+1\right]} \text{ and } E = \frac{r(1-b)}{2q}\left(2 - \frac{1}{\left[N(1-s)\right]+1}\right),$$

where $b = \dfrac{c}{pqK} = \dfrac{x^{\infty}}{K}$ is the normalized and x^{∞} is the actual open-access equilibrium stock level ($0 < b < 1$). We exclude the cases $b = 0$ for costless harvesting and $b = 1$, which would imply stock extinction and no commercial harvesting. Furthermore, the corresponding steady-state stock level becomes $x = K\left[1 - \dfrac{2N(1-s)+1}{2N(1-s)+2}(1-b)\right]$. The rent of each participant is $\pi_p = \dfrac{rpK(1-b)^2}{4Ns\left[N(1-s)+1\right]}$ and the rent of each non-participant is $\pi_{np} = \dfrac{rpK(1-b)^2}{4\left[N(1-s)+1\right]^2}$. The total rent of the fishery is $\Pi = rpK(1-b)^2\left[\dfrac{2N(1-s)+1}{4\left[N(1-s)+1\right]^2}\right]$.

Full cooperation exists when $s = 1$, in which case (3) is meaningless. The fully cooperative solution is given (see also Long 2009):

$$e(1) = \frac{r(1-b)}{2qN};\ x(1) = K\frac{1+b}{2};\ \pi(1) = \frac{rpK(1-b)^2}{4N};\ \Pi(1) = \frac{rpK(1-b)^2}{4}.$$

Note that the fully cooperative solution is a special case of the above solutions.

The non-cooperation occurs when no coalition exists in the Stackelberg game. Since non-cooperation results in the Nash–Cournot stable equilibrium (Pintassilgo and Lindroos 2006), we obtain (see also Long 2009):

$$e(0) = \frac{2N}{(N+1)}e(1);\ x(0) = \frac{(1+Nb)}{(b+1)(N+1)}x(1);\ \pi(0) = \frac{4N}{(N+1)^2}\pi(1);\ \Pi(0) = \frac{4N}{(N+1)^2}\Pi(1).$$

When $N = 2$, there are only non-cooperation or full cooperation strategies. It is easily verifiable that each country is always better off in the case of full cooperation. Therefore, full cooperation always exists (see also Long 2009). It should also be noted that at $s = 1/N$, there is no coalition. Clearly, this is not the case of an RFMO. Hereafter, we assume that $N > 2$ and $s \in \left[\dfrac{2}{N}, 1\right]$.

In the examination of coalition formation, the three following important indicators will be considered. The first is the payoff gap between a non-participant and a participant:

$$\mathrm{G} = \pi_{np}(s) - \pi_p(s) = \left[\frac{2Ns-(N+1)}{Ns\left[N(1-s)+1\right]^2}\right]\Pi(1)$$

The second is the incentive indicator for defecting from the cooperative coalition, assuming that this single defection does not cause all the other parties to the cooperative coalition also to defect:

$$\mathrm{D} = \pi_{np}(s-1/N) - \pi_p(s) = \left[\frac{1}{\left[N(1-s)+2\right]^2} - \frac{1}{Ns\left[N(1-s)+1\right]}\right]\Pi(1).$$

A non-positive defection indicator means that there will be no gain for a participant that leaves the existing coalition. This means that the cooperative coalition has achieved internal stability (see D'Aspremont *et al.* 1983). The third is the incentive indicator for free riding, which is given by:

$$\text{F} = \pi_{np}(s) - \pi_p(s + 1/N) = \left[\frac{1}{[N(1-s)+1]^2} - \frac{1}{(Ns+1)[N(1-s)]}\right]\Pi(1).$$

A non-negative free riding indicator means that there exists a gain, including zero, for a singleton if it stays outside the cooperative coalition. Thus, the cooperative coalition has achieved external stability (see D'Aspremont *et al.* 1983).

To ensure the long-term conservation and sustainable use of straddling fish stocks, the UNFSA has called for and established a framework for cooperation in utilizing these marine fisheries. The above results lead to some bio-economic implications for cooperation. It is important to note that the following propositions are based on the assumptions of the stock growth and catch functions in (1) and revenue and cost functions in (2). The proofs for the propositions are presented in Annexes 1–4.

Proposition 1: *If the level of cooperation in utilizing a straddling fish stock increases,* $s \in \left[\frac{2}{N}, 1\right]$, *we have (for* $N > 2$ *and* $0 < b < 1$*) the following implications:*

1.1. The steady-state fish stock level increases.

1.2. The total resource rent increases.

1.3. The rent of a non-participant increases, except when $s = 1$.

1.4. The rent of a participant decreases in $s \in \left[\frac{2}{N}, \frac{N+1}{2N}\right]$, *then increases in* $s \in \left[\frac{N+1}{2N}, 1\right]$, *and reaches the maximum level at full cooperation,* $s = 1$.

1.5. The income gap between a non-participant and a participant is larger than or equal to zero when $\frac{N+1}{2N} \le s \le \frac{N-1}{N}$ *and negative when* $\frac{2}{N} \le s < \frac{N+1}{2N}$, *except when* $s = 1$.

1.6. The incentive indicators for defecting and free riding are not always positive.

The explanation behind Propositions 1.1 and 1.2 is that, when more countries join the cooperative coalition, the total equilibrium fishing effort, $E = \frac{r(1-b)}{2q}\left(2 - \frac{1}{[N(1-s)]+1}\right)$, will decrease. This leads to an increase in the steady-state fish stock. Since the positive effect of an increase in stock on resource rent is higher than the negative effect of this decrease in total fishing effort, this makes an increase in the total rent of the fishery. These results were also found in the other extreme case with the Cournot game (see Long 2009). In general, an increase in the level of cooperation in straddling stock fisheries leads not only to the higher steady-state fish stock, but also to the higher total rent of the fishery. This is a very important rationale for the call to establish a framework for the cooperative use of straddling stock fisheries.

The explanation for Proposition 1.3 is that, in the Stackelberg model, there is a strategic effect for the leader to expand harvest in order to get the follower to contract harvest (see Naito and Polasky 1997). Hence, there are situations (with sufficiently small coalitions), where a country is better off as a member of the cooperative coalition than it is outside the cooperative coalition, and as the cooperative coalition grows, its members' rent deteriorates. When more countries join in the cooperative coalition, each of the remaining singletons will increase its fishing effort, leading to an increase in rent per non-participant. This is in line with the positive externality in fisheries in the case of the Cournot game proved by Pintassilgo and Lindroos (2006).

Proposition 1.4 can be justified as follows. Since there is a strategic effect for the cooperative coalition to expand harvest in order to get the singletons to contract harvest, if more countries join in the coalition, the participants' fishing effort will decrease. On the other hand, Proposition 1.1 demonstrates that, if more countries participate in the coalition, the steady-state fish stock will increase. Thus, there are situations (with sufficiently small coalitions) where the negative effect of a participant's fishing effort is still larger than the positive effect of the steady-state fish stock on a participant's rent, leading to a decrease in the participant's rent when there is an increase in the level of cooperation. At some degree of cooperation level, as the coalition grows, the situation becomes inverted and an increase in cooperation level will lead to an increase in the participants' rent. This relationship implies the 'U' shape of the participants' rent regarding the level of cooperation in utilizing straddling stock fisheries in a Stackelberge game. Within a Cournot game, Long (2009) also found this relationship. However, the reason for his finding is the 'U' shape of the participants' fishing effort regarding the level of cooperation in the Cournot game.

Propositions 1.5 and 1.6 show that some countries must gain a higher resource rent when playing cooperation than when playing defect, irrespective of the number of other countries that play defect or cooperation. This means that playing defect is not a dominant strategy in this game. As argued above, it is important to find out the stable equilibriums for the game of sharing a fish stock. D'Aspremont *et al.* (1983) supposed two requirements for a stable coalition. First, it is a single coalition from which no member wishes to withdraw (the cooperative coalition is internally stable). The incentive indicator D for defecting is therefore non-positive. Second, no non-member wishes to join the existing coalition (the cooperative coalition is externally stable). This means that the incentive indicator F for free riding is non-negative. Note that *Ns* is an integer. These lead to Proposition 2 as follows:

Proposition 2: *A stable RFMO in a commercial straddling stock fishery ($0 < b < 1$)*
2.1 For a given number of countries participating, we have:
2.1.1 Full cooperation is a stable coalition for $N \leq 4$.
2.1.2 When $N > 4$, a stable partial cooperation always exists at s^*. Specifically, when $N = 2k$ (k is an integer value), $s^* = \frac{N+2}{2N}$ *and when $N = 2k+1$,* $s^* = \frac{N+3}{2N}$. *Moreover, the size of the stable coalition (s^*) is slightly larger than that for which the resource rent of the participants is at its minimum.*
2.2 When $N > 4$, if, however, more countries are involved in the fishery, the level of cooperation at the stable equilibrium is reduced. There are, however, at least 50% of countries joining the cooperative coalition.

The intuition behind Proposition 2.1 is that, because of a strategic effect, the leader expands harvest in order to get the follower to contract harvest; when the number of countries involved in a shared fish stock is small enough (four or fewer), a country will recognize that it will be better off to play cooperate. If, however, more countries are involved in the fishery, an individual country may gain more harvest if it leaves the cooperative coalition. At the level of cooperation $s = s^*$, no country wants to join or leave the cooperative coalition. In addition, Proposition 1.4 shows that the members' rent is at its minimum at the level of cooperation $s = \frac{N+1}{2N}$. Clearly, since *Ns* is an integer, the size of the stable coalition (s^*) is slightly larger than that for which the rent of the participants is at its minimum. Finally, the explanation for Proposition 2.2 comes directly from Proposition 2.1.2 when *N* comes to infinity.

Proposition 2 gives a more optimistic prediction for the prospects of cooperation in utilizing a straddling fish stock than the other extreme case of the Cournot game proposed by Pintassilgo and Lindroos (2006). They have proved that, within the Cournot game of choosing fishing effort among the cooperative coalition and singletons, the Nash–Cournot stable equilibrium is the non-cooperative case when the number of countries involved in a shared fish stock, *N*, is more than two. A comparison of the result of Proposition 2 and non-cooperation leads to the next proposition.

Proposition 3: *At the stable equilibrium in a Stackelberg game, not only is the steady-state fish stock higher, but also the total resource rent of the fishery, participants' rent and non-participants' rent are higher than those of the Cournot–Nash stable equilibrium when* $N > 2$.

Proposition 3 has an important implication for the role of an RFMO in utilizing a shared fish stock in two extreme cases. In the Cournot game, the RFMO and the singletons simultaneously maximize their payoffs, taking the effort levels of the others as given. The RFMO in the Stackelberg game, however, acts as a Stackelberg leader and takes into account its ability to influence the singletons' output by choosing its own fishing effort with endogenous effort levels of the singletons. Levhari and Mirman (1980) also compared a Stackelberg and a Cournot model. In their duopoly model, each agent harvests only once per period. They demonstrated that, given the stock size, a Stackelberg game yields a greater equilibrium harvest and a smaller equilibrium steady-state stock than does a Cournot game. The reason is that there is a strategic effect when the leader expands harvest in order to get the follower to contract harvest in a Stackelberg game (see Naito and Polasky 1997). However, the explanation for Proposition 3's result is that the strategic effect is present in our model as well, but it is dominated by the effect of reducing the number of singletons because of the open membership characteristic of the cooperative coalition. This leads to a higher level in the steady-state fish stock, total rent of the fishery and individual rent in the Stackelberg equilibrium compared with those in the Cournot equilibrium.

Next, we investigate the new-entrant issue in straddling stock fisheries in this Stackelberg game. New entrants are previously inactive fishing countries which now enter a straddling stock fishery (see e.g. Pitassilgo and Costa Duarte 2001, McKelvy *et al.* 2003 and Pintassilgo *et al.* 2008). A reason for this may be that the relative costs of fishing (i.e. opportunity costs) or the absolute costs of these countries have decreased, making fishing now profitable (see Pintassilgo *et al.* 2008). Suppose some new players enter a straddling stock fishery. The next proposition considers the effect of new entrants on the potential for cooperation when three or more countries exploit a straddling fish stock within this Stackelberg game.

Proposition 4: *The new-entrant issue*
4.1 In any cooperative coalition,
4.1.1 if new players act as singletons, the steady-state fish stock level, the total rent of the fishery and the rent per country are reduced.
4.1.2 if new players join the cooperative coalition, the steady-state fish stock level and the total rent are unchanged, but the rent per coalition member is reduced.
4.1.3 when $s \geq s^*$, *if new players join the cooperative coalition, the rent per coalition member is always higher than if the new players act as singletons.*
4.2 In a stable coalition $(N \geq 4)$,
4.2.1 when N = 2k, if the number of the new players is 2d+1 (2d), then d+1 (d) new players join the RFMO and d (d) new players act as singletons (d is an integer, including zero). Moreover, if new players sequentially enter the fishing game, the $2d+1^{th}$ *entering player joins the cooperative coalition and the* $2d^{th}$ *entering player acts as a singleton such as the first entering player joins the cooperative coalition, the second entering player acts as a singleton and so on.*
4.2.2 when N = 2k+1, if the number of the new players is 2d+1 (2d), then d (d) new players join the RFMO and d+1 (d) new players act as singletons. Moreover, if new players sequentially enter the fishing game, the $2d^{th}$ *entering player joins the cooperative coalition and the* $2d+1^{th}$ *entering player acts as a singleton such as the first entering player acts as a singleton, the second entering player joins the cooperative coalition and so on.*

Proposition 4.1.1 suggests the negative effect of new entrants on the potential for cooperation if the new players act as singletons. This is consistent with Pintassilgo *et al.* (2008) in the case of the Cournot game with heterogenous harvesting costs. The intuition behind Proposition 4.1.2 is that, because of a strategic effect, the cooperative coalition expands harvest in order to get the follower to contract harvest; and that the former members have to share the rent with the new member(s) because of the open membership rule of an RFMO. Clearly, Propositions 4.1.2 and 4.1.3 demonstrate that, at any cooperation level higher than or equal to s^*, the participation of new players in the existing coalition leads not only to the higher steady-state fish stock, but also to the higher total rent and individual rent than if the new players act as singletons. In the other way, if the cooperative coalition does not accept the new players of the fishery as its new members, not only the steady-state fish stock, but also the total and individual resource rent will become worse. This is a rationale for the open membership characteristic of the cooperative coalition in straddling stock fisheries.

Assume that there exists a stable coalition managing a straddling stock fishery. Moreover, assumes that if new-comers want to joint the existing coalition, they will be accepted as new members and the former members will share the rent with the new members. Proposition 4.2 gives an important implication for the new entrant issue. If there is only a new-comer joining the fishery, it will participate this coalition in the case $N = 2k$ but it will not in the case $N = 2k+1$. However, if the number of new entrants is two new players or more, there are more or less a half of them which have an incentive to act as singletons. This result shows that even if a stable coalition managing a straddling stock fishery with the open membership rule exists, the new-entrant issue is still a problem for the conservation of this fish stock in this Stackelberg game.

POLICY IMPLICATION AND CONCLUSION

This paper uses a static approach with the classical Gordon–Schaefer model to examine the potential of cooperation in utilizing a straddling fish stock when the cooperative coalition of countries acts as a Stackelberg leader in which the cooperative coalition takes the fishing efforts of the remaining singletons as endogenous variables. We demonstrate that an increase in the cooperation level in utilizing a straddling fish stock leads to an increase not only in the steady-state fish stock, but also in the total rent of the fishery. This result is also found in the other extreme of a Cournot game in which the cooperative coalition and the singletons simultaneously maximize their payoffs, taking the effort levels of the others as given (see Long 2009). It may be an important rationale for a possible explanation of the UNFSA for cooperation in conserving and utilizing a straddling fish stock.

The study also shows that the strategic advantage of the cooperative coalition in a Stackelberg game is a reason for the more optimistic prospects of cooperation in utilizing a straddling fish stock. Specifically, when the cooperative coalition acts as a leader, the grand coalition is a Nash stable equilibrium outcome only if there are no more than four countries involved in a straddling fish stock. In addition, there is always a stable partial coalition for the exploitation of a straddling fish stock when the number of countries involved in the fishery is more than four. Hannesson (1997) used the repeated game and also found that the number of agents who will cooperate in setting the exploitation rate for a shared fishery is quite limited. Pintassilgo and Lindroos (2006), in contrast, showed that a non-cooperative solution is the inevitable outcome when the number of agents is more than two and the grand coalition is a Nash stable equilibrium outcome only if there are two countries sharing a fish stock in the case of a Cournot game. With a closer inspection of two stable equilibriums in Stackelberg and Cournot games, this paper also demonstrates that, when N is greater than two, the strategic advantage of the cooperative coalition leads not only to the steady-state fish stock, but also to the total rent, participants' rent and non-participants' rent being higher, though it reduces the number of singletons.

This study shows the negative effect of new entrants on the potential for cooperation if the new players act as singletons. This is consistent with Pintassilgo *et al.* (2008) in the case of a Cournot game with heterogeneous harvesting costs. Moreover, at any cooperation level higher than or equal to its stable cooperation level, the participation of new players in the existing coalition leads to the higher steady-state fish stock, total rent and individual rent than if the new players act as singletons. This may be an important rationale for the suggestion of Lodge *et al.* (2007) that, in each RFMO, the members should seek means of accommodating new members, such as allowing new members to purchase or lease fishing rights from existing RFMO members. However, it is important to note that even if a stable coalition managing a straddling stock fishery with the open membership rule exists, the new-entrant issue is still a problem for the conservation of this fish stock in this Stackelberg game.

Full cooperation is the optimum in utilizing a straddling fish stock in the Stackelberg game since it gives not only the highest level of steady-state fish stock, but also the highest levels of total rent and participants' rent. However, there exists an incentive for any participant to defect from the cooperative coalition at full cooperation when *N* is greater than four. This is also found in a Cournot game when *N* is greater than two (Pintassilgo and Lindroos 2006). Even the restrictions set by the UNFSA, prohibiting non-member states that do not abide by the regime of the regional fishery organization in fishing the resource, the UNFSA is binding only upon those states that are party to it. Some countries may refuse to be party to the UNFSA to gain the advantage of being free riders. This may be an explanation for the recommendation that the RFMO members should recognize the grave threat to the stability of the cooperative regime posed by IUU fishing and work vigorously towards the suppression and elimination of such fishing (Lodge *et al.* 2007).

According to the present research, the prospects of cooperation in utilizing a straddling fish stock are not unlikely if the cooperative coalition acts as a leader. This is an important implication for policymakers when discussing an agreement for establishing an RFMO to manage a straddling fish stock. It is, however, important to note that this study assumes that every member of the RMFO will comply with the terms of the agreement they have signed. This assumption means that every member will trust the compliance of others with the terms of agreement, with costless enforcement. If the cost for enforcing RFMO members' compliance with the terms of agreement is high enough, there may not be any incentive for fishing countries to establish an RFMO for managing a straddling fish stock (see Long (2009) for the case of a Cournot game). This is a reason for pervasive over-fishing around the world.

Following the vein of Pintassilgo *et al.* (2008), future studies may consider countries sharing a fish stock with a heterogeneous unit effort cost, catchability coefficient and unit harvest price. Case examination of more complex specifications of the resource rent, cost and harvest functions and dynamic analysis may also be a natural extension of the present research.

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ENDNOTES

[1] Counting the EU fishing nations as one makes the number of entities less than ten, but additional distant-water nations' vessels may appear.

[2] So far, this introduction partly overlaps with that of Long (2009).

[3] Naito and Polasky (1997) have also considered the case that the singleton countries dissipate any remaining rents in the open-access 'outside coalition' fishery. It makes sense to assume that an RFMO with an open membership characteristic will attract all singletons if the profit of the coalition is positive. Therefore, this case is ignored in this study.