STABILITY OF INTERNATIONAL FISHERIES AGREEMENTS – IMPLICATIONS OF NON-MARKET BENEFITS AND THE COUNTRY OF ORIGIN

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ABSTRACT

Salmon is an anadromous species that during its feeding and spawning migrations is sought after catch for commercial and recreational fisheries. The management of salmon fisheries is complicated by the combination of mixed and single stock fisheries. Thus, the country of origin has sovereign control over harvest of a salmon stock only at the last steps of the gauntlet. This paper addresses the stability of an international fisheries agreement on the Baltic salmon. This setting is modeled through a coalition game in the partition function form with four asymmetric players. Countries payoffs depend both on commercial fishery's profits and net benefits from recreational harvest. Moreover, the country of origin must ensure that each of the salmon stocks achieve or maintain a sustainable size. The economic sub-model is calibrated using commercial fisheries statistics and existing non-market valuation studies. The underlying population dynamics model accounts for 15 salmon stocks and it is used in the actual stock assessment. The results indicate that by considering economic aspects of recreational fisheries it is possible to stabilize the grand coalition. However, the cooperative strategies of the grand coalition do not ensure biologically sound harvesting of all salmon stocks.

INTRODUCTION

The literature on international fisheries agreements (IFAs) shows the *Paradox of the Global Commons* [1], that is, the higher the benefits from cooperation the harder it is to achieve a successful agreement. This is due to the existence of positive externalities on coalition formation, which means that free riders benefit from others cooperating and aiming at sustainable harvesting. The present paper contributes to this literature by studying the impact of non-market values on the stability of international fisheries agreements. It has been shown that, in the presence of transfers between members of an IFA, the existence of asymmetries between players increases the prospects of cooperationa. For instance, [2] show that both partial and full cooperation can be achieved, depending on the number of players, asymmetry and efficiency levels. In this paper we model the stability of an IFA on the salmon fisheries in the Baltic Sea through a four-player game of coalition formation. Two players (Denmark and Poland) have a commercial fleet only, whereas the others (Finland and Sweden) have both commercial fleet and substantial recreational fisheries. The recreational benefits are an extra source of asymmetry between players and increase the aggregate net benefits from the salmon fishery.

BIOECONOMIC MODEL

The game theoretical analysis presented here builds on the model by [3]. We adjust their counterfactual analysis by projecting the fishery forward, accounting for the recreational fisheries and updating the commercial fleet description with the latest regulations. Moreover, the population dynamic model, which accounts for 15 wild salmon stocks, is populated by the parameter values from the latest stock assessment [4]. The commercial fleet profits follow the functional forms and estimates adopted from [3]. The four players of the game are Poland (PL), Denmark (DK), Finland (FI) and Sweden (SE). Poland and Denmark harvest salmon in winter using longlines (LL). Finland harvest salmon using longlines and trapnets (TN) and the Swedish commercial fleet applies only trapnets. Finland and Sweden have also recreational (RI) fisheries that target salmon in their home rivers where the salmon reproduces. Recreational fisheries harvest what has escaped from the commercial fisheries. The salmon that escapes recreational fishery spawns and dies after it. Due to the migration routes the number of salmon available to each fleet is different and thus each fleet has a different effect on the dynamics of each salmon stock (Table I).

Table I: Fleet structure of each country and the target salmon stocks of each fleet. The stocks with recreational fisheries are shown in bold.

Salmon stock	PL	DK	FI			SE	
	LL	*LL*	*LL*	*TN*	*RI*	*TN*	*RI*
Tornionjoki	x	x	x	x	x		x
Simojoki	x	x	x	x	x		
Kalixälven	x	x	x	x			x
Råneälven	x	x	x	x			
Piteälven	x	x	x	x		x	
Åbyälven	x	x	x	x		x	
Byskeälven	x	x	x	x		x	x
Rickleån	x	x	x	x		x	
Sävarån	x	x	x	x		x	
Ume/Vindelälven	x	x	x	x		x	x
Öreälven	x	x	x	x		x	
Lögdeälven	x	x	x	x		x	
Ljungan	x	x	x	x		x	
Mörrumsån	x	x	x				x
Emån	x	x	x				

Recreational net benefits

In modeling the net benefits of the recreational harvest we assume a linear marginal willingness to pay (WTP) for recreational harvest and in order to estimate the individual net benefit function, compute the integral of the estimated marginal WTP between the current and improved catch levels [5]. These individual net benefits are then aggregated across the approximate angler population to obtain parameters of the aggregated net benefit function: $NB=kH-vH^2$, where H, is the salmon catch and k and v functional parameters. Based on existing contingent valuation studies we take the WTP estimates for rivers Simojoki [6], Tornionjoki (both in the Finnish and the Swedish side) [7], Byskeälven [8], and Ume/Vindelälven [9]. Moreover, we assume that the number of anglers and anglers preferences in rivers Kalixälven and in Mörrumsån are similar to those in Tornio (Swedish side) and Byskeälven, respectively. Table II presents the parameters of the net benefit function for each river.

Table II: Parameters of the river fisheries net benefit functions.

	k	v
Byskeälven	11.52	0.0006
Simojoki	46.54	0.0062
Torniojoki, Finland	22.51	0.0004
Torniojoki, Sweden	24.43	0.0027
Ume/Vindelälven	3.89	0.0022

COALITION FORMATION GAME

We use a coalition game in the partition function form to study which kind of international agreements between the four countries are possible to form. A partition function assigns a value to each coalition (see rows named as 'Partition' in the Tables III-V). In our game, a coalition can consist of one to four players and its objective is to maximize its economic net benefits from the fishery. The coalition members play cooperatively within the coalition. This means that they share the aggregate worth of the coalition. We apply the Almost Ideal Sharing Scheme (AISS) that allocates to each coalition member its free rider payoff plus a share of the coalition surplus (rows named as 'Valuation' in the Tables III-V) [10]. The coalition plays non-cooperatively against non-members. That is, the coalition maximizes its benefits while knowing that the free riders, singleton(s), are maximizing theirs. As explained earlier, one key characteristic of fishery games is positive externalities. Thus, we test if that applies to our game, by checking if the free rider payoffs increase when coalitions are formed. For example, we compare the payoff of Poland and Denmark in a case where all four countries are singletons (see Table III, coalition structure 1) to their payoffs when Finland and Sweden merge (see Table III, coalition structure 2). If the non-members payoffs increase when coalitions are formed, considering all possible coalitions, then the game exhibits positive externalities. To test the stability of coalitions we use the concepts of internal and external stability. A coalition is internally stable (IS) if none of the members finds it optimal to leave the coalition. It is externally stable (ES) if none of the non-members finds it optimal to join the coalition. Coalition is stable if it is both internally and externally stable.

RESULTS

We analyze three scenarios which are explained below. Common to all scenarios is that the strategies shown in the Tables III-V are the Nash equilibrium strategies with respect to the reported fishing efforts in year 2010. That is, these are constant effort strategies during the simulation period, 2011-2030, which correspond to a proportion of the effort level in the base year (2010). The partition and value functions are presented in thousands of Euros. A common result to each scenario is that the game exhibit positive externalities.

Scenario1: Commercial fisheries only

In the Scenario 1 (S1) the objective function of each country includes only the net present value of the commercial fisheries profits in years 2011-2030 and the strategy space of each country includes commercial effort. The results show that the total payoffs under non-cooperation and under grand coalition are 18.8MEUR and 55.9MEUR, respectively (Table III). However, the grand coalition is not stable. The highest total payoff under a stable agreement is 48.1MEUR, which would be a result of an agreement between Poland, Denmark and Finland (coalition structure 10, C10). Under this agreement Finland would undertake all the harvest of the coalition and share the profits of the commercial fishery among all the three coalition members according to the AISS.

Scenario 2: Recreational net benefits included, but the recreational fisheries are not part of the strategy space

In the Scenario 2 (S2) the objective function of Poland and Denmark includes the net present value of the commercial fisheries profits. The objective function of Finland includes the net present value of the LL and TN profits and the net benefits from the rivers Simojoki and Tornionjoki recreational fisheries. The objective function of Sweden includes the net present value of TN profits and the net benefits from recreational fisheries of river Tornionojoki, river Kalixälven, River Byskeälven, River Ume/Vindelälven and river Mörrumsån. The strategy space of each country includes only commercial effort. The results show that in the non-cooperative game (C1), it would be optimal for Sweden not to harvest at all in the commercial fishery and earn net benefits from the recreational fisheries yielding 31.5MEUR (Table IV). The grand coalition (C12) is stable and its optimal strategy, leading to an aggregate payoff of 139MEUR, is to stop commercial fishery and keep the river fishery effort constant.

Scenario 3: Recreational net benefits included, and the recreational fisheries are part of the strategy space

In the Scenario 3 (S3) the objective functions are the same to those in Scenario 2, but the recreational fisheries are included now in the strategy space. The Nash equilibrium strategies for the Finnish and Swedish recreational fisheries are shown in parenthesis (Table V). The results show that the grand coalition is stable and Sweden would be the only harvester. The Nash equilibrium strategies for Swedish commercial and recreational fisheries are 3.8 and 1.9 times the level of the base year, respectively. The value of grand coalition is 253.6 MEUR.

Implications for salmon stocks

Figure 1 illustrates the number of juvenile salmon (smolts) under the different scenarios and coalition structures. The present management objective of achieving 75% of the potential smolt production capacity is shown by the horizontal dotted line. The results show that non-cooperative solution (C1) yields less smolts than stable cooperative solutions under all scenarios (S1-S3). In the long run, rivers Torninojoki, Kalixälven and Ume/Vindelälven will achieve the management objective under all the shown options. In terms of the smolt production target, the grand coalition under the scenario 2 (S2/C12) would be the best. This option would stop the commercial fishery and maintain the recreational fishery effort at its present level. However, in economic terms the best agreement would be the grand coalition under the scenario 3 (S3/C12). This outcome would nearly double the recreational fishing effort in the Swedish rivers. As a consequence, given the present management objective, this would be too high effort for river Mörrumsån.

Table III: Results of the Scenario 1. Coalition strategies and stable coalition structures are shown shaded.

1) Commercial fisheries only									
Coalition structure			Poland	Denmark	Finland	Sweden	Total	IS	ES
1	PL,DK,FI,SE	Strategy	1.8	2.6	3.2	1.2	18762	yes	yes
		Valuation	5576	495	11594	1098			
		Partition	5576	495	11594	1098			
2	(FI,SE)	Strategy	1.8	2.8	3.4	0	20965	yes	yes
		Valuation	5808	633	12510	2014			
		Partition	5808	633	14524	0			
3	(DK,FI)	Strategy	1.8	0	3.6	1.4	23104	yes	no
		Valuation	6581	1758	12857	1909			
		Partition	6581	14615	0	1909			
4	(PL,FI)	Strategy	0	6.6	3.8	2.4	30520	yes	yes
		Valuation	6893	4745	12911	5971			
		Partition	19804	4745	0	5971			
5	(DK,SE)	Strategy	1.8	0	3.4	1.6	22993	yes	no
		Valuation	6656	838	14059	1441			
		Partition	6656	2278	14059	0			
6	(PL,SE)	Strategy	0	6.4	4	2.4	30369	no	yes
		Valuation	5033	4556	20226	555			
		Partition	5587	4556	20226	0			
7	(DK,PL)	Strategy	1.8	0	3.6	1.4	23104	yes	no
		Valuation	5831	750	14615	1909			
		Partition	6581	0	14615	1909			
8	(FI,SE,DK)	Strategy	2	0	3.6	0	24014	yes	yes
		Valuation	7182	710	14136	1986			
		Partition	7182	16832	0	0			
9	(PL,FI,SE)	Strategy	0	7.2	3.8	0.4	33137	no	yes
		Valuation	4274	5732	18693	4438			
		Partition	27405	5732	0	0			
10	**(PL,DK,FI)**	Strategy	0	0	3.8	4.2	48097	yes	yes
		Valuation	7419	5584	15453	19640			
		Partition	28457	0	0	19640			
11	(PL,DK,SE)	Strategy	0	0	4.6	3.8	45501	yes	yes
		Valuation	7204	5104	30735	2457			
		Partition	14766	0	30735	0			
12	(PL,DK,FI,SE)	Strategy	0	0	0.8	4.6	55887	no	yes
		Valuation	5331	3882	28885	17790			
		Partition	55887	0	0	0			

Table IV: Results of the Scenario 2. Coalition strategies and stable coalition structures are shown shaded.

2) Recreational net benefits included, but recreational fishery is not part of the strategy space									
Coalition structure			Poland	Denmark	Finland	Sweden	Total	IS	ES
1	PL,DK,FI,SE	Strategy	2	3.8	1.20	0	64293	yes	yes
		Valuation	6876	1082	24795	31540			
		Partition	6876	1082	24795	31540			
2	(FI,SE)	Strategy	2.2	4	0	0	69284	yes	no
		Valuation	7605	1160	26887	33632			
		Partition	7605	1160	60520	0			
3	(DK,FI)	Strategy	2.2	0	1.60	0	69667	yes	no
		Valuation	8839	2456	26169	32203			
		Partition	8839	28625	0	32203			
4	(PL,FI)	Strategy	0	8	2.40	0.6	80109	yes	no
		Valuation	9687	7076	27605	35742			
		Partition	37291	7076	0	35742			
5	(DK,SE)	Strategy	2.2	0	1.60	0	69667	no	no
		Valuation	8839	873	28625	31330			
		Partition	8839	32203	28625	0			
6	(PL,SE)	Strategy	0	8	2.40	0.6	80109	no	no
		Valuation	5539	7076	37291	30203			
		Partition	35742	7076	37291	0			
7	(DK,PL)	Strategy	2.2	0	1.60	0	69667	yes	no
		Valuation	7316	1522	28625	32203			
		Partition	8839	0	28625	32203			
8	(FI,SE,DK)	Strategy	2.20	0	0	0	81870	yes	no
		Valuation	10151	4404	31869	35446			
		Partition	10151	71719	0	0			
9	(PL,FI,SE)	Strategy	0	9.6	0	0	96938	yes	no
		Valuation	9724	9941	39411	37862			
		Partition	86997	9941	0	0			
10	(PL,DK,FI)	Strategy	0	0	3.40	2.40	98363	yes	no
		Valuation	10674	8911	30461	48317			
		Partition	50046	0	0	48317			
11	(PL,DK,SE)	Strategy	0	0	3.40	2.40	98363	yes	no
		Valuation	8906	7142	50046	32269			
		Partition	48317	0	50046	0			
12	**(PL,DK,FI,SE)**	Strategy	0	0	0	0	139165	yes	yes
		Valuation	15329	15119	55223	53495			
		Partition	139165	0	0	0			

Table V: Results of the Scenario 3. Coalition strategies and stable coalition structures are shown shaded.

3) Recreational fisheries is included in the strategy space									
Coalition structure			Poland	Denmark	Finland	Sweden	Total	IS	ES
1	PL,DK,FI,SE	Strategy	1.4	1.8	3 (1.5)	3.4 (1.7)	84296	yes	yes
		Valuation	4113	262	20245	59676			
		Partition	4113	262	20245	59676			
2	(FI,SE)	Strategy	1.8	2.8	0 (0)	3.6 (1.8)	113333	yes	no
		Valuation	5812	635	33727	73158			
		Partition	5812	635	106886	0			
3	(DK,FI)	Strategy	1.6	0	3 (1.5)	3.4 (1.7)	88339	yes	no
		Valuation	4976	627	20609	62127			
		Partition	4976	21236	0	62127			
4	(PL,FI)	Strategy	0	5.4	3.4 (1.7)	3.4 (1.7)	114530	yes	no
		Valuation	7906	3277	24038	79310			
		Partition	31943	3277	0	79310			
5	(DK,SE)	Strategy	1.6	0	3 (1.5)	3.4 (1.7)	88339	yes	no
		Valuation	4976	1357	21236	60770			
		Partition	4976	62127	21236	0			
6	(PL,SE)	Strategy	0	5	3.4 (1.7)	3.6 (1.8)	115817	yes	no
		Valuation	13101	2876	31176	68664			
		Partition	81764	2876	31176	0			
7	(DK,PL)	Strategy	1.6	0	3.4 (1.7)	3.4 (1.7)	88339	yes	no
		Valuation	4413	563	21236	62127			
		Partition	4976	0	21236	62127			
8	(FI,SE,DK)	Strategy	1.8	0	0	3.6 (1.8)	134069	yes	no
		Valuation	7441	14845	35446	76337			
		Partition	7441	126628	0	0			
9	(PL,FI,SE)	Strategy	0	7.6	0	3.6 (1.8)	165617	yes	no
		Valuation	20022	6689	45386	93520			
		Partition	158928	6689	0	0			
10	(PL,DK,FI)	Strategy	0	0	3.8 (1.9)	3.6 (1.8)	155624	yes	no
		Valuation	10963	9264	27223	108174			
		Partition	47450	0	0	108174			
11	(PL,DK,SE)	Strategy	0	0	3.8 (1.9)	3.6 (1.8)	155624	yes	no
		Valuation	17708	15608	47450	74858			
		Partition	108174	0	47450	0			
12	**(PL,DK,FI,SE)**	Strategy	0	0	0 (0)	3.8 (1.9)	253609	yes	yes
		Valuation	28405	27653	68414	129137			
		Partition	253609	0	0	0			

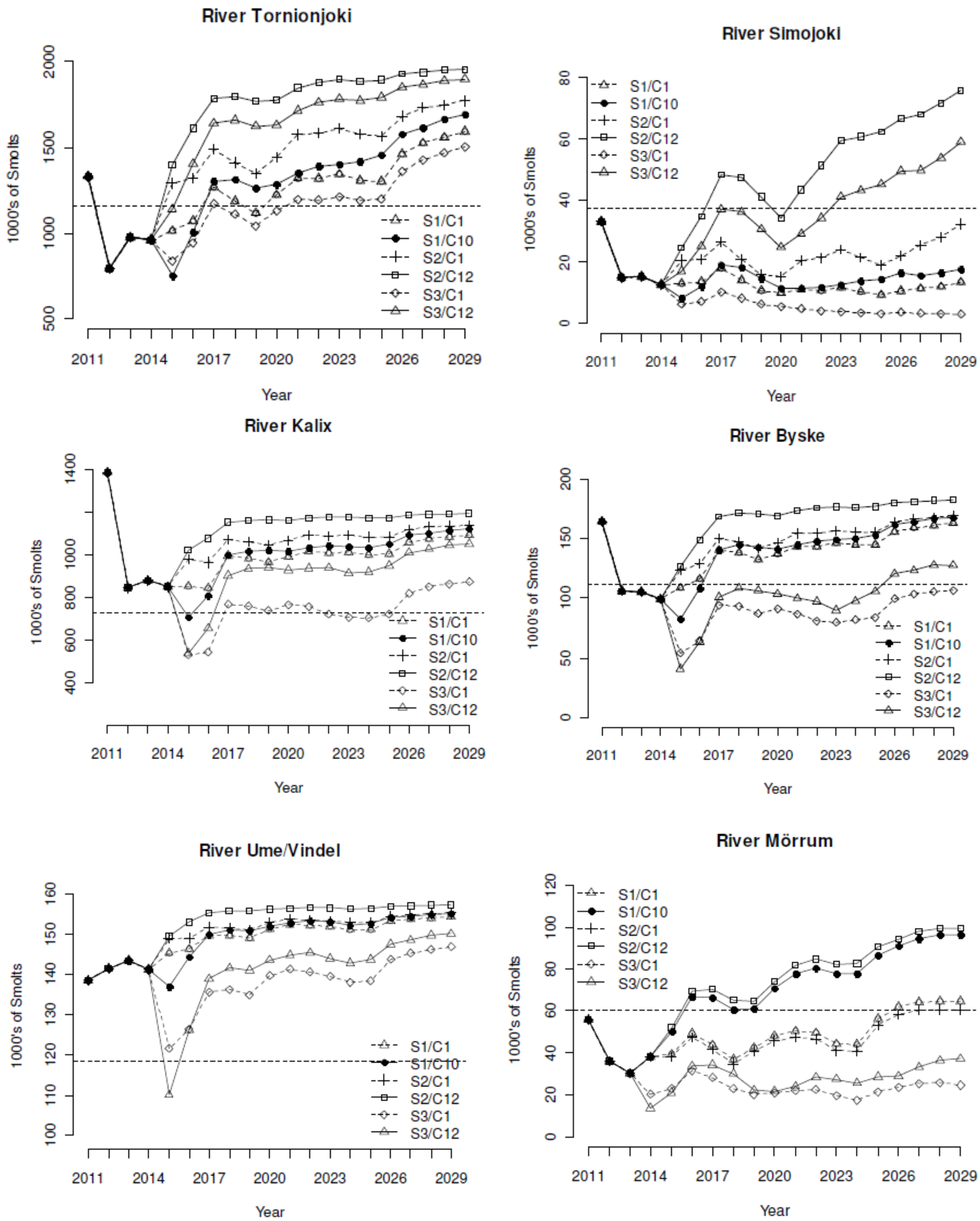

Figure 1. The number of smolts under different scenarios (S) and stable coalition structures (C).The horizontal dotted lines shows the 75% of the estimated median smolt production capacity (ICES 2012).

DISCUSSION AND CONCLUSION

The present paper studies the impact of non-market values on the stability of an international fisheries agreement. The preliminary results show that despite the existence of positive externalities accounting recreational benefits increases the chances of stable grand coalition. Thus the results support the earlier findings in the IFA literature according to which the more asymmetric the players are the more successful cooperation, given that a transfer scheme exists. Though the recreational benefits help to achieve stable grand coalition and increase the economic benefits from the fishery substantially, the biological management objective is not fully met. The result presented here are preliminary and more computational power is needed to study how robust the results are for the changes in parameter values. A worthwhile extension would be a game setting where recreational and commercial fisheries would be the players.

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