

ATLANTIC SALMON FISHERY IN THE BALTIC SEA - A CASE OF TRIVIAL COOPERATIONⁱ

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ABSTRACT

This paper analyses the management of the Atlantic salmon stocks in the Baltic Sea through a coalition game in partition function form. The signs of economic and biological over-exploitation of these salmon stocks over the last two decades indicate that cooperation among the harvesting countries, under the European Union's Common Fisheries Policy (CFP), has been ostensible. Combining a two-stage game of four asymmetric players with a disaggregated bioeconomic model, we conclude that cooperation under the present Relative Stability Principle (RSP) is not a stable outcome. In contrast, the equilibrium of the game is full non-cooperation. The paper also addresses the possibility of enhancing cooperation through more flexible fishing strategies. The results indicate that partial cooperation is stable under specific sharing schemes. It is also shown that substantial economic benefits could have been realised by reallocating the fishing effort, without compromising stock sustainability.

Keywords: partition function, coalition formation, sharing rules, stability analysis, bioeconomic model, Atlantic salmon

INTRODUCTION

The Atlantic salmon of the Baltic Sea is a valuable resource shared by several coastal states. Damming, pollution, overfishing and changes in the Baltic Sea ecosystem have caused a serious decline in the wild, naturally reproducing, salmon stocks. Therefore, in 1997 the now defunct International Baltic Sea Fishery Commission (IBSFC) launched the Baltic Salmon Action Plan (SAP) that aimed to recover wild Baltic salmon stocks. The goal was to reach 50 % of estimated smolt production capacity by 2010. Presently it is expected that only some of the more productive salmon stocks will reach this goal. Furthermore, as the political situation in the region changed after the last enlargement of the EU, the European Commission decided to revise the SAP in 2008 and to develop a new management framework for Baltic salmon [1].

The present reproduction areas of this anadromous species are mainly located in Finland and Sweden. In addition to these two countries, during its feeding and spawning migrations, salmon is harvested mainly by Denmark and Poland. The salmon fishery in the Baltic Sea is regulated by the European Union's Common Fisheries Policy (CFP) that determines each country's total allowable catch (TAC). Added to this, each country has its own regulations, for instance regarding the length of the fishing season.

The salmon TAC in the Baltic Sea region is shared among the EU countries according to the Relative Stability Principle (RSP) (EEC Reg. no. 172/83) that assures to each member state a fixed percentage of the catch volume yearly available. The total TAC is a result from the political decisions based on scientific salmon stock assessment. Based on the RSP each member state knows the total TAC level required to maintain its TAC high enough (see e.g.[2]). Consequently, member states have an incentive to "talk up" the total TAC. Such a situation is called decision-overfishing [3].

Salmon catches in the Baltic Sea have declined since 1990 from 5.600 tonnes in 1990 to 1.275 tonnes in 2006, which was the lowest registered catch since 1970 [4]. Despite the decline in the catches, the TAC

has been set so high that it does not restrict the fishery. Since early 1990's, the reported salmon catches have been near 70% of the TAC (see e.g [3]). Further, the number of fishing vessels in the offshore salmon fishery has decreased from 316 vessels in 1996 to 98 vessels in 2006 [4]. Consequently, CFP appears to have failed in its objectives to maintain sustainable salmon stocks and economically viable fishing industries. This seems to happen despite the enormous number of biological (see e.g [5,6]) and management related studies (see e.g.:[7-9] on the Baltic salmon. Studies addressing the economic dimensions of the Baltic salmon fisheries are, however, scarce. [10-12] studied the optimal harvest of salmon from the Finnish point of view and [13] expanded the focus to internationally optimal harvest. The poor state of the salmon stocks in the Baltic Sea and the low catches compared to the TACs, raise a fundamental question: does a real cooperative management of the species exists? To answer this question we construct a bioeconomic model and analyse strategic interactions between the fishing states through a coalition formation model.

The earlier studies on the cooperative management of the migrating fish stocks have used characteristic function (C-function) games to address the sharing of cooperative surplus (see e.g. [14-16]). Recently, games in the partition function (P-function) form have been introduced in the fisheries literature [17,18]. P-function games are able to analyse potential externalities of coalition formation, i.e. the effects that mergers produce on the non-merging players. These effects are assumed to be absent in the case of C-function games. Fishery games generally exhibit positive externalities, that is, when some fishing states join together in a coalition the other states benefit from it. This generally occurs as the coalition tends to reduce its fishing effort in order to better manage and safeguard the fish stock. The states outside the coalition benefit from those efforts, through an increase in stock availability. In this context, free rider incentives tend to be present and therefore the grand-coalition is rarely an equilibrium outcome [19].

We apply a P-function approach to assess the equilibrium of the Salmon fishery in the Baltic Sea and confront it with the past and present status of the fishery. The coalition formation is modelled as a single-coalition and open-membership game [20], based on a fairly disaggregated bioeconomic [13]. This paper fills a gap in the literature by providing an empirical application of coalition formation in fisheries. In particular, it is directly related to previous theoretical studies such as [21,22]. The former analyses coalition formation in fisheries using the classical Gordon-Schaefer bioeconomic modelling [23,24]. The latter proposes a sharing scheme to distribute the gains from cooperation in coalition games with externalities.. Further, the present paper addresses the following question raised by [25]: "As hard as the analysis may be the heterogeneity of players raises the interesting and important issue of the composition of coalitions: Do coalitions in a stable coalition structure [...] consists of similar players or dissimilar players or both?" Due to the migration pattern of salmon, the catch of different countries has a different effect on different salmon stocks. Consequently, our detailed analysis of potentially stable coalitions will give insights into the planning and implementation of the forthcoming SAP. For instance, what are the potential socio-economic and biological effects of a management system where the feeding salmon in the Baltic Main Basin is regulated separately from the spawning migrating salmon in the Gulf of Bothnia?

BIOECONOMIC MODEL

The underlying bioeconomic simulation model on which we base our coalition game follows [13]. The model considers four fishing states controlling on near 80% of the TAC and catching 90% of the annual salmon catch: Finland, Sweden, Denmark and Poland, which differ among other things in terms of the structure of the salmon fleet, fishing costs and salmon price. We review shortly this highly disaggregate and sequential model in those parts that are necessary to understand the present analysis and results.

The underlying population model is used by the Baltic Salmon and Trout Assessment Working Group (WGBAST) to assess the status of the salmon stocks and to provide management recommendations [4,26]. Figure 1 illustrates the population dynamics and the sequential fishery. The adult salmon recruit mainly to the fishery during its feeding migration to the Baltic Main Basin. There, salmon is harvested by offshore driftnets and longlines which we denote by ODN and OLL, respectively. All four countries

participate in these fisheries. The offshore fisheries take place in the winter time and by assumption the offshore driftnet fishery harvest in October and the longliners in December. In the spring time, the mature salmon start their spawning migration towards their home rivers. Then, the homing fish are harvested by coastal driftnet (CDN), coastal trapnet (CTN) and coastal gillnet (CGN) fisheries in the Bothnian Sea and in the Bothnian Bay. Finland and Sweden are the only countries participating in the coastal fisheries. Finally, the salmon is harvested by river fisheries, which are mainly recreational. The present analysis exclude the value of the recreational catch, however the model accounts for the effect of the river fisheries on the salmon stocks.

The population dynamics model considers the life-history of 15 naturally reproducing salmon stocks, two of which locate in Finland and the remainder in Sweden. The migration route of salmon is dependent on the location of their home rivers. Therefore, it affects the stock available for each gear type and country. Further, the model considers the life-cycle of hatchery-reared salmon and its contribution to the salmon catches. These facts are encompassed on the economic part of the model that assesses each country's net present value from the fishery. The model considers years 1995-2005. Thus, it allows us to compare the real performance of the fishery with those that could have occurred under alternative economically sound fishing policies.

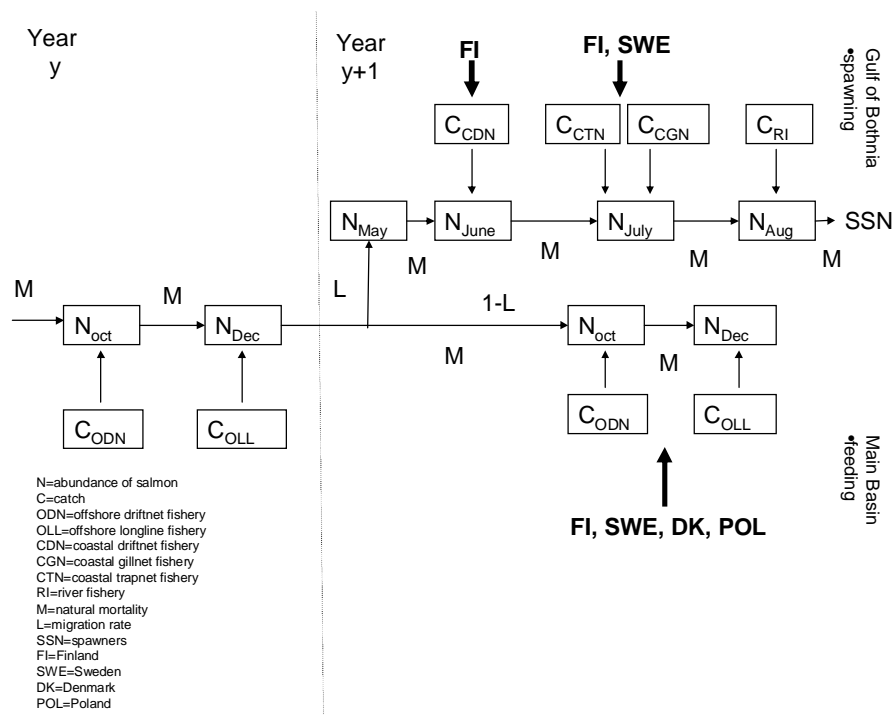


Fig. 1. Schematic presentation of the bioeconomic model.

THE GAME

In this section we define a two-stage partition function game in order to understand the strategic interaction between the countries. As referred, all four countries are members of the European Union and they operate under the Common Fisheries Policy. However, something in the TAC negotiations does not fit the picture, since the TAC has been higher than reported catches and, most importantly, the salmon stocks have decreased.

Coalition Formation Model

We study the coalition formation in the salmon fishery by applying the simultaneous-move and open-membership game. For instance, [17,21] have adopted the same approach in addressing straddling fish stocks. The game consists of two stages. In the first, players decide whether to behave as singletons or to join a coalition. We adopt the assumption of only one non-trivial (non-singleton) coalition (see e.g.[22]). Therefore, each player can only choose to play as singleton or to join the coalition. In the second stage, singleton(s) and coalition play non-cooperatively by choosing the fishing effort strategies that maximise their payoffs, given the behaviour of the others. The game is solved by backward induction for the Nash equilibrium coalition structure.

Partition Function

Throughout the paper we follow the definitions and notation of [22]. We denote our coalition game between the n ($= 4$) players by $\Gamma(N, \pi)$. A coalition S is defined as a subset of the set of players $N = \{1, \dots, n\}$ and the set of all possible coalitions of N is represented by 2^N . However, we restrict our analysis to coalition structures consisting of only one non-trivial coalition S while all other players $j \in N \setminus S$ are singletons. This approach is, therefore, a special case of the general definition of partition functions defined for instance by [27]. Consequently, each country can only be in the coalition or outside it. Therefore, each coalition structure is fully characterized by coalition S . We define a restricted partition function π that assigns a single real number $\pi_S(S)$ to coalition S and real numbers $\pi_j(S)$ to each singleton coalition as:

$$\pi: S \text{ a } \pi(S) = (\pi_S(S), \pi_j(S)) \in \mathbb{R}^{1+(n-s)} \quad \text{with } j \in N \setminus S. \quad (\text{Eq.1})$$

The domain of the restricted partition function is the power set of N (2^N) i.e. the partition function takes this set as input. The image of this mapping is a vector with variable size, $(1+(n-s))$ where s is the number of players in the coalition (cardinality of coalition S).

Since we are interested in analysing the players' incentives to form coalitions, we need to define how each player values the coalitions. Therefore, we define a valuation function v to each coalition that prescribes how the worth of coalition S is allocated among its members. A valuation function assigns to every coalition S of N a real-valued vector of length n , $v: 2^N \rightarrow \mathbb{R}^n: S \text{ a } v(S)$, such that:

$$\begin{cases} \sum_{i \in S} v_i(S) = \pi_S(S) \\ v_j(S) = \pi_j(S) \quad \forall j \in N \setminus S. \end{cases} \quad (\text{Eq.2})$$

Valuations $v_i(S)$ satisfies group rationality, meaning that the entire worth of coalition S , $\pi_S(S)$, is allocated to its members. For each singleton, the valuation $v_j(S)$ coincides with the worth $\pi_j(S)$ that is assigned to the singletons by the partition function. As equation (2) shows the valuation specifies the payoff for the coalition members and the singletons and does this for all possible coalitions. Therefore, each player is able to evaluate its gains from each coalition structure. Consequently, valuations fix the sharing rule of the cooperative surplus.

Let us now define formally the concepts of positive externalities and superadditivity and global efficiency. A coalition game $\Gamma(N, \pi)$ exhibits positive externalities if and only if its partition function

π satisfies: $\forall S \subseteq N, \forall j \neq i, j \notin S : \pi_j(S) \geq \pi_j(S \setminus \{i\})$.ⁱⁱ Positive externalities imply that the remaining singletons do not lose when coalitions merge.

A coalition game $\Gamma(N, \pi)$ is superadditive if and only if its partition function π satisfies: $\forall S \subseteq N, \forall i \in S : \pi_S(S) \geq \pi_{S \setminus \{i\}}(S \setminus \{i\}) + \pi_i(S \setminus \{i\})$. Superadditivity implies that the value of the coalition must be at least as the value of the coalition when one player deviates plus the payoff of the deviator after deviation. Thus, superadditivity implies that a merger does not decrease the aggregate welfare of the merging players.

Finally, we say that a coalition game $\Gamma(N, \pi)$ is globally efficient if and only if:

$\forall S \subset N, \forall i \in N \setminus S : \pi_S(S \cup \{i\}) + \sum_{j \in N \setminus (S \cup \{i\})} \pi_j(S \cup \{i\}) \geq \pi_S(S) + \sum_{j \in N \setminus S} \pi_j(S)$. As proved by Bloch (2003), if a partition function is superadditive the grand coalition is always the most efficient coalition structure. However, if the game is both superadditive and exhibits positive externalities, the grand coalition may not be stable. That happens if the free rider incentives due to the positive externalities exceed the superadditivity effect.

Stability Concept

We adopt the definition for stable coalition due to [20]. According to it coalition S is considered to be stable with respect to the valuations $v(S)$ if and only if S is both internally and externally stable. A coalition game $\Gamma(N, \pi)$ is internally stable (IS) if and only if: $\forall i \in S : v_i(S) \geq v_i(S \setminus \{i\})$. Internal stability implies that no coalition member finds it optimal to leave the coalitionⁱⁱⁱ. A coalition game $\Gamma(N, \pi)$ is externally stable (ES) if and only if: $\forall j \in N \setminus S : v_j(S) \geq v_j(S \cup \{j\})$. External stability (ES) implies that no singleton finds it optimal to join the coalition. As defined earlier, the valuation function specifies how the worth of coalition S is allocated among its members. Therefore, as there are several valuation functions that can be derived from a single partition function, a coalition S may be stable with respect to a particular valuation function but not be with respect to another.

RESTRICTED EFFORT STRATEGIES

The present section presents the preliminary results^{iv} of the game that is constructed to reflect fisheries policy under the Relative Stability Principle (RSP). The objective of the coalition members is to maximise the sum of their net present value (NPV) from the salmon fishery given that the players outside the coalition also maximize their NPV. The maximisation of the coalition is however constrained by the restriction that all coalition members harvest and they adopt the same proportional change to the fishing efforts reported in the period 1995-2005 [4]. Throughout the paper, it is assumed that the strategy space of each country is bounded below by zero and upper by the fishing strategy that the country would adopt if it were the sole exploiter of the stock (see e.g.[28]). We denote the reported fishing effort of country n , in

year t , by $E_{n,t}^{rep}$. The strategy of country n is defined as: $X_{n,t} = \frac{E_{n,t}}{E_{n,t}^{rep}}, X_{n,t} \in [0, \bar{X}_n]$, where \bar{X}_n is the upper bound of the strategy space.

Table 2 illustrates the partition function $\pi(S)$ and valuation function $v(S)$ for each coalition structure. The partition function assigns a value for the coalition $\pi_S(S)$ and for the singleton coalition

$\pi_j(S), \forall j \in N \setminus S$ and the valuation function prescribes how the worth of coalition is allocated among its members. Except for the singleton coalition and the full cooperative coalition structure, the value of the coalition $\pi_S(S)$ and its allocation $v_i(S), \forall i \in S$ is shown in shaded. The results show that the merger of coalitions generally increases the payoff of the non-merging players, for example when Finland and Sweden form a coalition (2) the payoffs of Denmark and Poland increases. However, this does not occur for all coalition structures and therefore game as a whole does not exhibit positive externalities. For instance, a coalition of Finland and Denmark (3) would decrease the payoffs of Sweden and Poland. This is due to the restriction according to which each member of the coalition harvests. In the non-cooperative case (1) it is optimal for Denmark not to harvest, however under restricted strategies it will harvest when it forms a coalition with Finland. This causes a decline in the salmon available to the rest of the countries.

Further, the results show that the game is not superadditive. That can be easily verified for instance by looking at coalition structure 8, where Finland, Sweden and Denmark form a coalition and Poland is a singleton. The value of the three player coalition is $\pi(S) = 926$ and if, for instance, Finland deviates the value of the coalition becomes $\pi_{S \setminus \{1\}}(S \setminus \{1\}) = 106$ and the payoff of Finland $\pi_1(S \setminus \{1\}) = 965$. This contradicts the definition for superadditivity since $926 < 1071$. Further, although the merger of coalitions generally increases the aggregate payoff there are exceptions. Thus, the game is also not globally efficient. For instance, if Denmark would join the coalition between Finland and Sweden the aggregate payoff would decrease (see coalitions 2 and 8).

Finally, the stability analysis shows that cooperation among the four countries cannot be stable, since the free rider benefits exceed the aggregate value of the grand coalition. Furthermore, the only stable coalition structure is full non-cooperation, where all the players are singletons. These results help to explain why the cooperation among the fishing states, under the auspices of the European Union, seems to be trivial. In the next section, we assess the prospects of effective cooperation under more flexible fishing strategies.

Table II. Partition and value functions in thousand's of euro's (t€) for the proportional shares strategies.

Coalition (S)		Finland	Sweden	Denmark	Poland	total	IS	ES	
		1	2	3	4				
1	(1),(2),(3),(4)	strategy	0.3	0.4	0	4.2	1623	yes	yes
		v(S)	919	165	0	539			
		$\pi(S)$	919	165	0	539			
2	(1,2), (3), (4)	strategy	0.3	0.3	0.1	4.2	1626	no	no
		v(S)	942	138	0.8	545			
		$\pi(S)$	1080		0.8	545			
3	(1,3), (2), (4)	strategy	0.3	0.3	0.3	4.2	1396	no	no
		v(S)	817	98	-18	499			
		$\pi(S)$	799	98		499			
4	(1,4), (2), (3)	strategy	0.3	0.7	0.8	0.3	2036	no	yes
		v(S)	1184	547	248	57			
		$\pi(S)$	1241	547	248				
5	(2,3), (1), (4)	strategy	0.3	0.2	0.2	4.2	1622	no	yes
		v(S)	965	102	3	551			
		$\pi(S)$	965	106		551			
6	(2,4), (1), (3)	strategy	0.4	0.6	0.7	0.6	1962	no	no
		v(S)	1263	415	177	107			
		$\pi(S)$	1263	522	177				
7	(3,4), (1), (2)	strategy	0.4	0.6	0.6	0.6	2095	no	no
		v(S)	1351	459	174	111			

		$\pi(S)$	1351	459	286	2095		
8	(1,2,3), (4)	strategy	0.2	0.2	0.2	4.5	5.1	
		$v(S)$	801	118	7	605	1531	
		$\pi(S)$		926		605	1531	no yes
9	(1,2,4), (3)	strategy	0.3	0.3	1	0.3	1.9	
		$v(S)$	1428	345	427	63	2263	
		$\pi(S)$	1835		427		2263	no yes
10	(1,3,4), (2)	strategy	0.3	0.8	0.3	0.3	1.7	
		$v(S)$	1450	831	138	65	2483	
		$\pi(S)$	1652	831			2483	no yes
11	(2,3,4), (1)	strategy	0.4	0.6	0.6	0.6	2.2	
		$v(S)$	1351	459	224	111	2145	
		$\pi(S)$	1351		794		2145	no no
12	(1,2,3,4)	strategy	0.3	0.3	0.3	0.3	1.2	
		$v(S)$	1999	531	219	78	2827	
		$\pi(S)$		2827			2827	no yes

OPTIMAL EFFORT STRATEGIES

The present section presents the preliminary results of the game in which each coalition adopts optimal fishing efforts for its members. Table 3 presents the partition function of the game. As expected, the coalition payoffs $\pi_s(S)$, shown in shaded, have increased relative to the previous scenario, whereas the outcome of the full non-cooperation remained unchanged. Here the most efficient member is the only harvesting country in all other non-trivial coalitions, except the grand coalition, where Finland and Sweden harvest jointly. Further, the aggregated value of all coalition structures increases, with the exception of (1) and (7). The results show that the game exhibits positive externalities and global efficiency but not superadditivity. Let us now study the conditions under which a coalition that yields higher aggregate payoffs than full non-cooperation would be stabilized. Within the coalition formation game a natural starting point is to look at the conditions under which a member would not find it optimal to leave the coalition. We follow [22] and define that a coalition S is potentially internally stable (PIS) for partition function π if and only if: $\pi_s(S) \geq \sum_{i \in S} (\pi(S \setminus \{i\}))$, i.e. the value of the coalition is at least equal to the sum of the free rider payoffs. The free-rider payoff is defined as the payoffs of a coalition member that leaves it to become a singleton, holding the rest of the coalition structure unchanged. Table 3 shows that the present game has six potentially internally stable coalitions, The two three-player-coalitions (8 and 10) are the most interesting cases, since the two-player-coalitions (3, 5 and 7) are neutral in terms of the coalitional benefits, when compared to full non-cooperation,. Further, the outcomes of the two PIS three-player coalitions are significantly different in terms of the aggregate payoff; .Finally, it is important to note that the full cooperation among the four countries is not PIS since the sum of the free rider payoffs 4118 t€ exceeds the aggregate worth of the coalition 3299 t€

Table III. Partition function in thousand's of euro's (t€) for the optimal strategies scenario.

Coalition(S)		Finland	Sweden	Denmark	Poland	total	PIS
		1	2	3	4		
1	(1),(2),(3),(4)	strategy	0.3	0.4	0	4.2	
		$\pi(S)$	919	165	0	539	1623
2	(1,2), (3), (4)	strategy	0.3	0.0	0.2	4.5	
		$\pi(S)$		1067	10	614	1691
3	(1,3), (2), (4)	strategy	0.3	0.4	0	4.2	
		$\pi(S)$	919	165		539	1623
4	(1,4), (2), (3)	strategy	0.4	0.6	0.8	0.0	

		$\pi(S)$	1399	500	271	2170	
		strategy	0.3	0.4	0	4.2	
5	(2,3), (1), (4)	$\pi(S)$	919	165	539	1623	yes
		strategy	0.4	0.6	0.8	0	
6	(2,4), (1), (3)	$\pi(S)$	1399	500	271	2170	no
		strategy	0.3	0.4	0	4.2	
7	(3,4), (1), (2)	$\pi(S)$	919	165	539	1623	yes
		strategy	0.3	0	0	4.5	
8	(1,2,3) (4)	$\pi(S)$	1204	666	1870	yes	
		strategy	0.4	0	1.2	0	
9	(1,2,4) (3)	$\pi(S)$	1788	575	2362	no	
		strategy	0.4	0.8	0	0	
10	(1,3,4) (2)	$\pi(S)$	1911	966	2876	yes	
		strategy	0.4	0.8	0	0	
11	(2,3,4) (1)	$\pi(S)$	1911	966	2876	no	
		strategy	0.5	0.1	0	0	
12	(1,2,3,4)	$\pi(S)$	3299	3299	3299	no	

Next we study how the coalition surplus, $\sigma(S) = \pi_S(S) - \sum_{i \in S} \pi_i(S \setminus \{i\})$, should be shared among the

coalition members in order to stabilize the potentially internally stable coalitions. We consider three different sharing rules: the Almost Ideal Sharing Scheme (AISS) suggested by [22] the Nash Bargaining solution and the Shapley value^v. We start by defining the three concepts. Recall, that a valuation function specifies how the worth of a coalition is allocated among its members. Consequently, for each valuation corresponds a unique sharing rule. First, we define the Almost Ideal Valuation Function (AIVF) for coalition game $\Gamma(N, \pi)$ as a valuation function $v^{AIVF(\lambda)}$ that satisfies:

$$\forall S \subseteq N : \begin{cases} \forall i \in S : v_i^{AIVF(\lambda)}(S) = \pi_i(S \setminus \{i\}) + \lambda_i(S) \sigma(S) \\ \forall j \in N \setminus S : v_j^{AIVF(\lambda)}(S) = \pi_j(S) \end{cases}$$

with $\lambda(S) \in \Delta^{s-1} = \left\{ \lambda \in \mathbb{R}_+^s \mid \sum_{j \in S} \lambda_j = 1 \right\}$, where Δ^{s-1} denotes the set of all possible sharing weights of a coalition with s players, and $\sigma(S)$ the coalition surplus, which can be positive, negative or nil. Consequently, an AIVF allocates to each coalition member its free-rider payoff plus some share, $\lambda(S)$, of the surplus. [29] developed a similar kind of sharing rule called "Satisfactory Nucleolus" for the C-function game.

Table 4 presents the stability analysis of the present game under the three sharing rules. We illustrate the AISS by using equal weights i.e. $\lambda_i(S) = \frac{1}{s}, \forall S \subseteq N, \forall i \in S$. [22] showed that the AISS stabilizes the PIS coalition that has the highest aggregate worth and therefore the sharing scheme can be regarded as optimal. Further, they showed that this result is robust with respect to the surplus allocation i.e. it does not depend on the sharing weights. Table 4 shows that AISS stabilizes the coalition between Finland, Denmark and Poland (10) which is the one that yields the highest aggregate payoff among those that are PIS. The Nash Bargaining solution presented in the Table 4 is computed as follows: $v_i^{Nash-B}(S) = \pi_i(\{i\}) + \lambda_i \left[\pi_S(S) - \sum_{i \in S} \pi_i(\{i\}) \right]$, where $\pi_i(\{i\})$ is the payoff of the player i under

full non-cooperation and $\lambda_i(S)$ satisfies: $\forall S \subseteq N, \forall i \in S: \lambda_i = \frac{1}{s}$. Consequently, the difference

between AISS and Nash Bargaining solution is that on the former the threat points depends on the coalition structure, whereas on the latter they are fixed and equal to the payoffs when all players are singletons. The results show that the Nash Bargaining solution is only able to stabilize the case of full non-cooperation.

The modified Shapley value is calculated according to the formula:

$$v_i^{Shap}(S) = \sum_{T \subseteq S} \frac{[t-1]![s-t]!}{s!} [\pi_T(T) - \pi_{T \setminus \{i\}}(T \setminus \{i\})] \quad \forall i \in S, \text{ where } s = |S| \text{ is the cardinality of the}$$

coalition S and similarly $t = |T|$ is the cardinality of the subset $T \subseteq S$. The Shapley value assigns to each coalition member its average contribution to every possible subcoalition T of S. Table 4 shows that the Shapley value stabilizes full non-cooperation and the coalition structure number 5, whose outcome coincides with that of full non-cooperation. Consequently, the results are in line with other studies focusing on the coalition formation with positive externalities [22,29] that showed the existence of other sharing rules that stabilize coalition structures with higher aggregate payoff than those corresponding to the Nash bargaining solution and the Shapley value.

Table IV. Valuation functions for the optimal effort strategies with three sharing rules.

Coalition(S)	AISS					Nash Bargaining					Shapley Value					
	1	2	3	4	IS ES	2	3	4	IS ES	1	2	3	4	IS ES		
1 (1),(2),(3),(4)	share v(S)	919	165	0	539	yes yes	919	165	0	539	yes yes	919	165	0	539	yes yes
2 (1,2), (3), (4)	share v(S)	0,85	0,15			no yes	0,85	0,15			no no	0,85	0,15			no no
3 (1,3), (2), (4)	Share v(S)	1		0		yes no	1		0		yes no	1		0		yes no
4 (1,4), (2), (3)	share v(S)	0,64			0,36	no no	0,64			0,36	no no	0,64			0,36	no no
5 (2,3), (1), (4)	share v(S)		1	0		yes yes		1	0		yes no		1	0		yes yes
6 (2,4), (1), (3)	share v(S)		0,13		0,87	no yes		0,13		0,87	no yes		0,13		0,87	no no
7 (3,4), (1), (2)	share v(S)			0	1	yes no			0	1	yes no			0	1	yes no
8 (1,2,3), (4)	share v(S)	0,79	0,17	0,04		yes yes	0,80	0,17	0,03		yes no	0,31	0,31	0,38		no no
9 (1,2,4), (3)	share v(S)	0,65	0,14		0,21	no yes	0,54	0,12		0,33	no yes	0,67	0,23		0,10	no no
10 (1,3,4), (2)	share v(S)	0,51		0,17	0,21	yes yes	0,56		0,08	0,36	no yes	0,31		0,38	0,31	no yes
11 (2,3,4), (1)	share v(S)		0,17	0,28	0,55	no yes		0,26	0,09	0,65	no yes		0,20	0,59	0,20	no yes
12 (1,2,3,4)	share v(S)	0,52	0,23	0,11	0,14	no yes	0,41	0,18	0,13	0,29	no yes	0,36	0,17	0,24	0,23	no yes
		1706	761	370	462		1338	584	419	958		1198	545	806	750	

CONCLUSIONS

The Atlantic salmon fishery in the Baltic Sea has shown clear signs of biological and economic over-exploitation, over the last two decades. Although all the Baltic Sea riparian countries considered are members of the European Union and agree on the annual fishing possibilities under the Common Fisheries Policy (CFP) the salmon quota has not restricted the fishery. The catches year after year below TAC suggest that the cooperation under the CFP framework has been trivial.

Using a game in partition function form, we show that, in fact, full cooperation is not a stable outcome, as the free rider payoffs exceed the payoffs of cooperation. Furthermore, full non-cooperation is the equilibrium of the game if the fishing strategies are according with the relative stability principle (RSP). The results also show that economically sound fisheries policies lead to higher stock levels than the historical performance of the international salmon fishery.

We also investigate the consequences of relaxing the RSP by allowing each coalition member to adopt its optimal strategy. The results show that under an appropriate sharing rule, the AISS, it is possible to achieve a high degree of stable cooperation between the countries, namely three-player coalitions such as Finland, Sweden and Denmark or Finland, Denmark and Poland. A change from fishing strategies accordant with RSP to the optimal fishing strategies, though reducing the number of active harvesting countries, increases the aggregate payoffs. Further, the sharing rule allocates the payoffs in such a way that stabilises the coalition to non-harvesting coalition members so that the coalition is stable. Finally, the model results show that the coalition structure where Finland, Denmark and Poland form a coalition yields the highest aggregate payoffs and is in accordance with the precautionary principle related to mixed stock fisheries.

The model results are significantly different from those obtained by [21]. Using the classical Gordon-Schaefer bioeconomic model in a symmetric player setting, the authors concluded that the only stable coalition structure is the one formed by singletons that is complete non-cooperation. Hence, our results indicate that by allowing for asymmetric players and considering disaggregated bioeconomic models it is possible to guarantee higher levels of cooperation. Extending the present empirical model opens several possibilities for further research, namely the study of the stability of coalitions over time and the role of uncertainty in coalition formation.

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ENDNOTES

ⁱ Do not cite without contacting the first author. The results are preliminary.

ⁱⁱ Eyckmans and Finus (2004) defines positive externalities: $\forall S \subseteq N, \forall j \neq i, j \notin S : \pi_j(S) \geq \pi_j(S \setminus \{i\})$ and $\exists k \neq i, k \notin S : \pi_k(S) > \pi_k(S \setminus \{i\})$. However, their results are robust to our more loose definition that considers also the neutral effects of coalition formation.

ⁱⁱⁱ Since the paper focus on only one non-trivial coalition, internal stability coincides with the stand alone stability defined by Yi (1997, p.223). According to it, a coalition structure is stand-alone stable if no player finds it optimal to leave its coalition to form a singleton coalition, holding the rest of the coalition structure constant.

^{iv} Do not cite without contacting the first author. The results are preliminary

^v We follow Eyckmans & Finus (2004) and apply the extended versions of the Nash Bargaining and Shapley value defined by Aumann and Drèze (1974) i.e. we calculate the values for all coalition structures.