Bargaining over Resource Regulation: Total Allowable Catch Setting in the European Common Fisheries Policy

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Abstract. A problem in TAC setting is that often the interests of the different stakeholders are unequally represented in the decision-making process putting economic interests in a better bargaining position than conservation interests. This imbalance can lead to ineffective TAC management. In order to analyze the distribution of bargaining power between different interests groups the TAC decision-making is modeled as a cooperative two-player-game with one player representing fishermen and fishing industry's interests and the other player representing conservation interests. Nash's bargaining solution of this game is used to derive an equation to estimate the bargaining powers. Panel data of TACs for European stocks are used for the estimation. The results show that the player representing interests of the fishermen and the fishing industry has the stronger bargaining position compared to the player representing conservation interests. The only exception are stocks that are fished by European Union member states but not managed by the Common Fisheries Policy. For those stocks, the player representing conservation interests has the stronger bargaining position leading to a more effective TAC management. The analysis also shows that scientific recommendations have a greater influence in the bargaining when the underlying data is of good quality. The conclusion is that effective TAC management requires both, a sound scientific assessment and a stronger inclusion of scientific advice.

Keywords: fisheries; fishery economics; bargaining power; political economy; cooperative game theory

JEL-Classification: Q22; Q71; D78

1 Introduction

Exploiting a renewable common pool resource such as fisheries in a non-cooperative way often leads to overexploitation or even distinction of the resource (Gordon 1954, Clark 1990). Cooperation between the groups of interests is the most promoted tool to overcome that problem (Kaitala and Lindroos 2007, Bailey et al. 2010). The European Union uses such a cooperative management for the European fisheries. The most important instrument is the total allowable catch (TAC) which defines the amount of fish that is allowed to be caught from a specific stock in a year. TACs are set for a wide range of stocks to restrict the fishing activities by setting catch limits. However, according to past evaluations of the European Common Fisheries Policy TACs have not been used to their potential (European Commission 2001; 2009). They often are set at too high levels leading to the failure of the fisheries management (Khalilian et al. 2010). This is not only a problem in the European Union but also apparent in other nations' fisheries policies (see e.g. Leal et al. (2010), Okey (2003)). A TAC does not restrict fishing at all if it exceeds the landings of the corresponding period. In that case TACs are not restrictive and fisheries are effectively unregulated, i.e. de-facto open access (Quaas et al. 2012). For 57% of the stocks examined in this paper landings reach 95% or less of the TAC. On average, TACs exceed landings by roughly 60%. TACs are set at binding levels for only 16% of all cases.[1] So, even if the decision on TACs is made in a cooperative framework, the solution does not necessarily guarantee a sustainable use of the resource. It is often argued that during the TAC bargaining process decision-makers have a rather short-term perspective (Franchino and Rahming 2003) or ignore scientific advice (Froese 2011). But this does not

[1] In the remaining 26% the landings exceed the TAC by more than 5%. In these cases the enforcement of the TAC regulation has probably not been strict enough. A prominent example of overfishing the TAC is the Polish cod fishery (ORCA-EU 2009).

need to hold for all decision-makers participating in the bargaining. There might also be decision-makers with a perspective on conservation that rely on the scientific recommendation. The problem then may be that the decision-makers of the second kind are underrepresented what can cause ineffective management (Okey 2003, Hilborn 2007).

This paper examines the bargaining position of different interests groups in the TAC bargaining process theoretically and in an empirical application to the European Union's TAC management. For the purpose of this analysis decision-makers, stakeholders and further interest groups are assumed to prefer a specific status quo TAC. For simplicity, I further assume that these status quo preferences can be classified into the two groups 'high TAC preference' and 'low TAC preference'. Using this kind of classification, the bargaining now takes place between two groups, i.e. two players, with opposing interests. I apply Nash's bargaining solution (Nash 1953) on this cooperative two-player-game in order to derive an equation that allows to estimate the bargaining power for each player using data on European stocks and their TACs. The analysis considers the distribution of bargaining power between the two players for the whole data set. It is also examined if this distribution changes in different fishing areas using subsets of the data.

In the following the set-up of the decision-making process for TACs in the European Union is described (section 2.1) and the game-theoretic background is explained (section 2.2). Section 3 describes the data that is used. Results are presented in section 4. The paper closes with a discussion of the findings in section 5.

2 Theoretical Model of Bargaining over TACs

2.1 Background: Decision-Making Process of TAC Setting in Europe

The formal decision-making process for the TAC setting is clearly defined (Churchill and Owen 2010). The European Commission prepares a proposal on TACs based on scientific input from research groups such as the Scientific, Technical and Economic Committee for Fisheries (STECF) and the International Council for the Exploration of the Seas (ICES). The proposal is handed to the European Council of Ministers. This Council currently consists of 28 national representatives, usually the ministers of agriculture and fisheries.[2] The ministers have to discuss the Commission's proposal and decide on the TAC levels. Until the latest reform of the Common Fisheries Policy, it has not been possible for other institutions, e.g. the European Parliament, to intervene or veto the Council's decision on TACs (e.g. European Council (2002), Art. 20). Hence, the ministers had the final say in this matter. However, since the adoption of the new Common Fisheries Policy in 2014 the European Parliament can intervene in the decision-making process of multi-annual plans where TACs are also included (European Union 2013). The observation period of the data used in this paper ends in 2013. Therefore, intervention of the European Parliament is not considered. It is important to note that there is a deadline for the ministers to fix the TACs (e.g. mid of January for stocks in European Union- and Non-European Union waters (European Council 2014a). Hence, the period of bargaining is limited. The ministers are obliged

[2] The number of members changed over time depending on the number of European Union member states.

to find an agreement, either by unanimity or by voting with qualified majority.[3] Given the minutes of the Council meetings discussing TACs, it seems that most of the TAC decisions are made by voting with at most three dissenting votes and/or abstentions (European Council 2014b). According to the formal decision-making process only the ministers are participating in this bargaining process. However, there are stakeholders on national and European Union level, such as producer and consumer organisations or NGOs, that affect this procedure and the ministers in an informal way. For simplification, I assume that the actors participating directly or indirectly in the TAC setting can be classified into two groups. One group comprises those actors who favor and support the conservation of fish stocks and a sustainable fisheries management. Members are e.g. scientists or environmental NGOs, such as Greenpeace or WWF, who clearly call for restrictive TACs. The second group comprises those actors who focus on profits (and hence catches) from fishing. Fishermen, the fishing and processing industry and producer organisations belong to this group. They call for TACs that do not restrict their fishing activities. Ministers can be part of either group. However, given the unsuccessful performance of the European TAC management in the past (European Commission 2001; 2009), and the fact that ministers had the final say regarding TACs it can be assumed that most of the ministers can be assigned to the second group. I further assume that the preferences regarding status quo TAC levels are different for each minister or stakeholder. Still, the status quo TAC preferences of actors of the same group are in the same range because members of the same group have similar interests. Hence, the preferred TAC level of each member of the first group

[3] In general, a qualified majority requires at least 255 out of 345 votes. Since 2014, a qualified majority "corresponds to at least 55% of the members, comprising at least 15 of them and representing at least 65% of the European population. A blocking minority may be formed comprising at least four members of the Council" (European Union 2015).

will be lower than the preferred TAC level of each member of the second group. Assuming now that the members of each group are homogeneous, each group can be seen as a player preferring a specific status quo TAC. Then, the bargaining process simplifies to a cooperative two-player-game with one player having a lower preferred status quo TAC than the other. The interesting question then is which player dominates the bargaining process.

2.2 Game Theoretic Approach

In the cooperative two-player-game it is each player's aim to set a TAC close to her preferred TAC level. However, the two players have to bargain since their preferences differ. This kind of game can be solved by applying the concept of the Nash bargaining solution (NBS) (Nash 1953, Binmore et al. 1986). The NBS is usually derived by maximizing the product of each player's difference in utilities of an agreement versus a disagreement, i.e. the Nash product. However, in the TAC bargaining process disagreement is not an option. Therefore, each player's aim is to minimize the deviation between their preferred option (disagreement) and the agreed-on TAC (agreement). Following the NBS notation the objective function then is:

$$\min_{TAC_t} \; (u_l(TAC_t) \; - \; u_l(REF_t))^{\alpha}(u_h(TAC_t) \; - \; u_h(REF_t))^{\beta} \tag{1}$$

with $u_l(\cdot)$ denoting the utility function of the player favoring low TACs, i.e. player l, and $u_h(\cdot)$ denoting the utility function of the player favoring high TACs, i.e. player h. The utility functions depend on the player's individual preferred status quo TAC, which is the reference value REF (in the case of disagreement), and the agreed-on TAC (in the case of agreement). In the NBS framework the exponents α and β can be interpreted as bargaining power parameter of each player if they sum up to one. It is therefore assumed that $\alpha + \beta = 1$. Also, players may differ in their bargaining power, i.e. $\alpha \neq \beta$. The higher the bargaining power parameter the smaller the deviation between agreed-on TAC and the player's preferred TAC and the higher the assertiveness of this player in equilibrium. In addition, it is assumed that $\alpha, \beta \in (0; 1)$.

The utility functions for players l and h are assumed to be:

$$u_l \;=\; \log(H_l^{-\delta}) \;\text{ and }\; u_h \;=\; \log(H_h^{\mu}) \tag{2}$$

with H indicating the amount of harvested fish and $\delta, \mu > 0$. Player l's utility decreases with the amount of harvested fish. The marginal utility loss is increasing the more fish has been harvested. This is because a stock's rebuilding capacity decreases if too much of the stock has been removed. Overexploitation or even extinction might be the consequence. Both have a negative impact on player l's utility. In contrast, player h's utility increases the higher the amount of harvested fish. However, the marginal utility is decreasing because of capacity and effort limits and decreasing fish prices.

For estimating the bargaining power of each player the following reference values, i.e. preferred status quo TACs, are assumed. The reference value of player l is the current scientific advice to the decision-makers based on stock assessment and further research with the intention to facilitate recovery and sustainable use of stocks. Player h orientates her reference value at the landings of the previous period. She demands a TAC which exceeds the previous landings by a certain percentage $\gamma > 0$, depending on stock characteristics (e.g. growth rate or market price), leading to a reference value of $(1+\gamma)L_{t-1}$. By that further restrictions in the future fishing activities are avoided.

Given that, equation (1) can be modified to:

$$\min_{TAC_t} \; (\log(TAC_t^{-\delta}) \;-\; \log(ADV_t^{-\delta}))^{\alpha} \, (\log(TAC_t^{\mu}) \;-\; \log(((1+\gamma)L_{t-1})^{\mu}))^{\beta}. \tag{3}$$

The terms in brackets denote the deviation in utility.

The TAC solving (3) is given by:[4]

$$TAC_t \;=\; \alpha(1+\gamma)L_{t-1}^{\alpha}ADV_t^{\beta}. \tag{4}$$

Equation (4) states that the final TAC in the current period t depends on the advice of the current period and the landings of the previous period. The advice captures the interests of player l while player h's interests are represented by the landings. The exponents α and β describe the bargaining power of player h and l, respectively. The higher the parameter the more the player's interests are affecting the final TAC. The assumption $\alpha, \beta > 0$ in equation (4) is verified. If there have been higher landings in the previous period player h will like to keep that level which puts pressure on the decision-makers to increase the TAC or at least does not motivate a decrease. Therefore, α has to be positive. Regarding the advice, it can be assumed that decision-makers will follow a recommended increase of the TAC. However, a recommended decrease is probably not implemented as willingly. The motivation for this is as follows. Assuming that player h has the stronger bargaining position (given the too high TACs in the past (European Commission 2001; 2009)) the decision-makers will rather follow player h's preferences which support an increase in TACs and disapprove a decrease in TACs. Either way, β has to be positive. Since $\alpha, \beta > 0$ and $\alpha + \beta = 1$ hold, the assumption $\alpha, \beta \in (0; 1)$ is also verified.

In order to quantify the bargaining power of the players l and h equation (4) is estimated.

3 Data

I use panel data for 73 fish stocks from European and Non-European waters in the Baltic Sea, North Sea and North East Atlantic. These 73 stocks represent 15

[4]See Appendix A.1 for calculations.

species: cod, haddock, herring, plaice, sole, whiting, anchovy, capelin, hake, horse mackerel, mackerel, megrim, Norway pout, saithe, sandeel and sprat (see Appendix A.2). For each stock a TAC is set each year. The time series of observations run from 1987 to 2013.[5] Data is available for the TAC (in tons), landings[6] (in tons), advice[7] (in tons) and information on the fishing area and the quality of the data underlying the assessment.[8] The data stem from the ICES advice sheets from 2014 (ICES 2014). If available, ICES estimates of landings are used. If these were not available official landing numbers reported by the countries are used. The advice sheets are used in the preparation of TAC proposals from the European Commission to the European Council of Ministers.

4 Estimation and Results

For the estimation, I take the logarithms of equation (4), and assume that the parameter γ depends on stock characteristics. There are 73 stocks from different areas fished by different countries which is why stock dummies are included. The stock dummies capture characteristics of the stocks that are not covered by the variables of landings and advice. Such characteristics can be the fishing area or biological and ecological specifications (e.g. stock size or reproduction behavior) that vary between stocks.[9] The resulting fixed-effect model is:

$$\log(TAC_{it}) = c + \alpha \log(L_{i,t-1}) + \beta \log(ADV_{it}) + \sum_{i=2}^{73} \tau_i dummy_i + \epsilon_{it} \quad (5)$$

[5]For the majority of the stocks data is available for the whole period. However, in some cases the time series starts later, e.g. because the TAC management was not introduced for all stocks at the same time.

[6]If not available, catch (in tons) is used. The catch includes landings and discard.

[7]Landings (or catches) according to the TAC recommended by the ICES.

[8]Ecoregion and more detailed area code is defined by the ICES.

[9]A t-test testing the null hypothesis of all stock dummies being jointly equal to 0 suggests to include stock dummies (Prob $>$ F = 0.0000).

with $c = \alpha(1+\gamma)$, $t = 1987, ..., 2013$ representing the year and $i = 1, ..., 73$ representing the stocks. Equation (5) has been estimated with the constraint that $\alpha + \beta = 1$. It is assumed that observations are independent between the groups, however, it is controlled for intra-group correlation.[10]

The results for α, β and c of estimating equation (5) are presented in table 1 (for the whole estimation output including stock effects see Appendix A.3).

		coefficient	SE	p-value	95% conf. interval	
$\log L_{t-1}$	α	0.5351	0.0776	0.000	0.3828	0.6874
$\log ADV_t$	β	0.4649	0.0776	0.000	0.3126	0.6172
	c	0.2449	0.0057	0.000	0.2338	0.2561
		No. of obs. = 1190	Prob. > F = 0.000		Root MSE = 0.1429	

Table 1: Estimation results of equation (5) for the whole data set under the constraint $\alpha + \beta = 1$.

Both coefficients, α and β, have a positive influence on the TAC level as expected. If the advice increases by 1% the TAC increases by 0.4679%. The landings' impact is higher. A 1% increase of landings leads to a 0.5351% increase of TAC. This implies that player h seems to have more bargaining power than player l. The results suggest that the interests of fishermen and the fishing industry have a stronger impact on the TACs than the interests of scientists and supporters of conservation. Most of the stock dummy coefficients have significant values indicating that there are stock-specific effects that have to be taken into account (see Appendix A.3).

The estimation results may be influenced by the quality of the scientific advice available. Although player h does not rely directly on the scientific advice, it can

[10] The calculations are done with STATA using the command cnsreg.

be assumed that she considers recommendations for TACs for orientation, e.g. for choosing the γ to set her preferred TAC value. The extent to which player h relies on the scientific advice might depend on the quality of the underlying data. A sound scientific assessment of a stock's situation allows to derive reliable advised TAC based on the assessment. The assessment of a stock for which only poor data is available is likely to be highly uncertain, which also implies that TAC advices based on the uncertain assessment might not be very reliable. As a consequence, the relevance of the scientific advice for stocks with poor data is decreasing which would weaken player l's bargaining position since her reference value equals the advised TAC. That in turn, would strengthen player h's bargaining position.

In each ICES advice sheet it is indicated whether the data is sufficient for an assessment or not. If the data is not sufficient, the ICES uses an approach for data-limited stocks for the assessment. To determine the influence of data quality, I classified the stocks according to the quality of data used for their assessment indicated in the ICES advice sheets of 2014 into the two groups 'good data' if data has been at least sufficient for the assessment and 'poor data' if the data-limited approach has been used. Then, I estimated equation (5) for both groups. Results regarding α, β and c are given in table 2 (for the whole estimation output including stock effects see Appendix A.4).

Player h has the better bargaining position in both subsets. However, in the subset of poor data her position is much stronger relative to player l's than in the subset of good data. Note that the coefficients are significantly different between the two groups. Thus, the quality of data matters in the bargaining process. If TACs for a stock with poor data for assessment are negotiated, player l's position is relatively weak, which might result in too high TACs since there is no sound scientific argument against it. On the other hand, if the data is good the scientific advice seems to have more influence in the decision-making.

		coefficient	SE	p-value	95% conf. interval	
Group 'Good Data'						
$\log L_{t-1}$	α	0.51456	0.0853	0.000	0.3471	0.6820
$\log ADV_t$	β	0.4854	0.0853	0.000	0.3179	0.6529
	c	0.2464	0.0062	0.000	0.2342	0.2587
	No. of obs. = 1033		Prob. > F = 0.000		Root MSE = 0.1402	
Group 'Poor Data'						
$\log L_{t-1}$	α	0.7099	0.0908	0.000	0.5304	0.8894
$\log ADV_t$	β	0.2901	0.0908	0.002	0.1106	0.4696
	c	0.1259	0.01169	0.000	0.1029	0.1491
	No. of obs. = 157		Prob. > F = 0.000		Root MSE = 0.1549	

Table 2: Estimation results of equation (5) for the subsets according to data quality under the constraint $\alpha + \beta = 1$.

4.1 Analysis by Fishing Area

In the previous section the whole data set was examined in order to get information on how the bargaining power in the TAC setting is distributed between player l favoring low TACs and player h favoring high TACs. This section examines to what extent the bargaining power of the two players differs between fishing areas. The motivation is as follows. Due to the regulation of fishing opportunities the countries are only allowed to fish for stocks for which they have a TAC (e.g. European Council (2002), European Union (2013)). Since most of the stocks can be assigned to a spatially limited habitat the fishing activities of countries is also spatially limited to specific fishing areas. In the TAC setting, all countries have a say even if they decide on TACs that are not relevant for them. Hence, the composition of actors (representing the interests of their home country) preferring a low status quo TAC or a high status quo TAC is likely to differ between fishing areas depending on whether the actors have an interest in stocks of this specific fishing area or not. That implies that the bargaining positions of players l and h also differ between fishing areas.

For the estimation by fishing area each stock is assigned to one of the following fishing areas:[11] Baltic Sea, North Sea, Celtic Sea and West of Scotland (in the following Celtic Sea), Bay of Biscay and Atlantic Iberian Waters (in the following Bay of Biscay), and the rest including Barent Sea, Icelandic Sea, Norwegian Sea, and East Greenland Sea (in the following Non-EU waters). Most of the stocks can be assigned to a single fishing area. Highly migratory stocks are assigned to all areas in which they are present. Then, equation (5) is estimated for each area over the whole time period from 1987 to 2013.

Area			coef.	SE	p-value	95% conf. interval	
	$\log L_{t-1}$	α	0.6994	0.0645	0.000	0.5722	0.8266
Baltic Sea	$\log ADV_t$	β	0.3006	0.0645	0.000	0.1734	0.4278
		c	0.3562	0.0023	0.000	0.3516	0.3607
No. of obs. = 199			Prob. > F = 0.000			Root MSE = 0.1816	
	$\log L_{t-1}$	α	0.5626	0.1186	0.000	0.3293	0.7956
North Sea	$\log ADV_t$	β	0.4374	0.1186	0.000	0.2041	0.6707
		c	-0.0191	0.0046	0.000	-0.0282	-0.0099
No. of obs. = 364			Prob. > F = 0.000			Root MSE = 0.1254	
	$\log L_{t-1}$	α	0.5599	0.0898	0.000	0.3829	0.7368
Celtic Sea	$\log ADV_t$	β	0.4401	0.0898	0.000	0.2632	0.6171
		c	0.2464	0.0166	0.000	0.2137	0.2792
No. of obs. = 257			Prob. > F = 0.000			Root MSE = 0.1149	
	$\log L_{t-1}$	α	0.6371	0.1223	0.000	0.3941	0.8801
Bay of Biscay	$\log ADV_t$	β	0.3629	0.1223	0.004	0.1199	0.6058
		c	0.2375	0.0089	0.000	0.2196	0.2552
No. of obs. = 98			Prob. > F = 0.005			Root MSE = 0.1547	
	$\log L_{t-1}$	α	0.1681	0.1159	0.149	-0.0603	0.3965
Non-EU	$\log ADV_t$	β	0.8319	0.1159	0.000	0.6035	1.0603
		c	0.0617	0.0345	0.075	-0.0063	0.1296
No. of obs. = 272			Prob. > F = 0.000			Root MSE = 0.1274	

[11] The corresponding fishing area for each stock is taken from the ICES advice sheets.

Table 3: Estimation results by area according to equation (5) under the constraint $\alpha + \beta = 1$.

The results regarding α, β and c are given in table 3 (for the whole estimation output see Appendix A.5). Landings and advice have positive coefficients throughout all fishing areas. In all European areas player h has the higher share of bargaining power ($\alpha > \beta$). The Baltic Sea shows the biggest imbalance of the players' bargaining powers followed by the Bay of Biscay. Here, scientific recommendation does not seem to be important in the TAC setting. Interests in profits from catches seem to dominate the discussion. For the North Sea and Celtic Sea bargaining powers are more evenly distributed. That could indicate that the representation of different interests is more balanced. In the Non-EU waters the opposite picture can be found. Player l has a very strong bargaining position relative to player h ($\alpha < \beta$). The estimated bargaining power of player h is even insignificant. Thus, player h does not seem to have an impact on the TAC negotiations. The stocks in these waters are mainly managed by Non-EU countries. From their agreed-on TAC a specific share is going to the European Union. The European Common Fishery Policy itself is not affecting the management in these waters as much as in EU waters. The high coefficient β might indicate that in the Non-EU countries scientific recommendations and conservation of stocks are more taken into account. This may lead to a more effective TAC management, as it is the case for Iceland (Hilborn 2007).

The differences in the bargaining power distribution in the TAC setting process in the different fishing areas might lead to differences in the performance of TAC management. A measure for the effectiveness or bindingness of TACs is the ratio of landings and TACs. I assume that a ratio between 0.95 and 1.05 indicates binding TACs.[12] A ratio below 0.95 implies that TACs have not been fully fished. Therefore they are too high and do not restrict the fishing activity as intended. A ratio greater than 1.05 implies that landings exceed the TAC. In that case, the TAC is at a restrictive level but not enforced properly.

Area	Baltic Sea	North Sea	Celtic Sea	Bay of Biscay	Non-EU
Mean Ratio	0.66	1.05	0.80	0.78	1.09
SD	(0.39)	(0.99)	(0.66)	(0.42)	(0.49)

Table 4: Mean ratio of landings and TACs by area from 1987 to 2013 (SD = standard deviation).

The mean ratio of the Baltic Sea is relatively low (0.66) indicating that TACs are set on too high and hence ineffective levels (table 4). This could be a consequence of the strong bargaining position of player h. TACs in the Celtic Sea and the Bay of Biscay seem to be more effective which could be caused by the relatively stronger bargaining position of player l. For the North Sea and Non-EU waters the TACs are at effective levels. In case of the Non-EU waters the ratio exceeds 1.05 which means that landings exceed the TACs by more than 5%. TACs could have been an efficient tool in this area. However, they have not been successfully enforced.

5 Discussion and Conclusion

This paper conceptualizes the political TAC setting process as a kind of Nash bargaining. It quantifies the bargaining power of the two players l and h representing the participating actors preferring low and high TACs, respectively, in order to

[12]Ideally, the ratio should equal 1. Then the TAC is perfectly binding. However, to account for uncertainties and inaccuracies a ratio $\in (0.95; 1.05)$ is also considered to indicate binding TACs.

examine how interests are represented in the decision-making process. The analysis has been done for the whole set of observations and for subsets according to fishing areas in order to capture different distributions of interests.

For the whole data set, player h (favoring high TACs) has a stronger position in the bargaining process than player l (favoring low TACs). The weak performance of the European TAC management therefore could be a result of the strong influence of fishermen, the industry, producer organisations and ministers who focus on profits from fishing, captured by player h. Scientific recommendations and interests in conservation of fish stocks, captured by player l, are less important. This is supported by the analysis by fishing area. In all EU areas, player h has a stronger bargaining position compared to player l leading to ineffective TAC levels. In contrast, in the Non-EU waters player l clearly dominates the bargaining process which could be one reason why the TAC management in these waters is more successful. The analysis also shows that a sound stock assessment based on good data improves the bargaining position of player l. In cases where only poor data has been available for the stock assessment player h's bargaining position is much stronger. If a reliable assessment is available the scientific recommendation for TACs is taken more into account. It is therefore very important to strengthen the position of the scientific input in the TAC bargaining process and to improve the data base underlying the scientific advice. Otherwise, it might be difficult to improve the TAC management's performance. Recognizing that, the Commission addressed this problem in the recent reform of the European Common Fisheries Policy (European Union 2013, European Commission 2009).

The estimations performed in this paper have been done under the constraint that the bargaining power parameters add up to one, i.e. $\alpha + \beta = 1$, to fit the assumptions of Nash's bargaining solution. The results of an unconstrained regression are given in Appendix A.6, A.7 and A.8. In this setting, player h also has the stronger bargaining position – in the whole data set as well as for the EU fishing area subsets. In the Non-EU fishing area player l has the much stronger bargaining position. However, the coefficients of player h and l do not add up to one in any of these estimations (this option is not even included in the confidence intervals, except for Bay of Biscay and the Non-EU waters). Hence, it can be argued that the cooperative two-player-approach might not be sufficient to capture all aspects of this bargaining process. Another approach could be to account for more differentiated interests groups and allow for three or more players. Then, the TAC bargaining could be modeled as a cooperative coalition game (Lindroos et al. 2007). Even if cooperation is possible between the players it can still be difficult to reach a cooperative solution. Munro (1979) considered side payments to overcome these difficulties. On the other hand, the contradiction to Nash's assumption could also suggest that a cooperative approach is not appropriate to model the TAC bargaining process – no matter how many players are involved. Hoffmann and Quaas (2015) argue that, assuming a non-cooperative setting, the institutional set-up of the TAC setting process in the European Union promotes short-term thinking and therefore leads to high TACs. They propose that binding long-term agreements including transfer payments solve that problem.

A Appendix

A.1 Nash Bargaining Solution

The Nash Bargaining Solution (NBS) can be derived by solving the minimization problem

$$\min_{TAC_t} \; (\log(TAC_t^{-\delta}) \; - \; \log(ADV_t^{-\delta}))^{\alpha} \; (\log(TAC_t^{\mu}) \; - \; \log(((1+\gamma)L_{t-1})^{\mu}))^{\beta} \quad (6)$$

The first order condition (FOC) is given by:

$$\begin{aligned} \alpha(\log(TAC_t^{-\delta}) \; - \; \log(ADV_t^{-\delta}))^{\alpha-1} \; \frac{-\delta}{TAC_t} \\ \cdot(\log(TAC_t^{\mu}) \; - \; \log(((1+\gamma)L_{t-1})^{\mu}))^{\beta} \\ + \; \beta(\log(TAC_t^{\mu}) \; - \; \log(((1+\gamma)L_{t-1})^{\mu}))^{\beta-1} \; \frac{\mu}{TAC_t} \\ \cdot(\log(TAC_t^{-\delta}) \; - \; \log(ADV_t^{-\delta}))^{\alpha} \; = \; 0 \end{aligned} \quad (7)$$

Rearranging yields:

$$\begin{aligned} 0 \; &= \; (-\delta)\alpha(\log(TAC_t^{\mu}) \; - \; \log(((1+\gamma)L_{t-1})^{\mu})) \; + \; \beta\mu(\log(TAC_t^{-\delta}) \\ &\quad - \; \log(ADV_t^{-\delta})) \\ 0 \; &= \; (-\delta)\alpha\mu \; \log\left(\frac{TAC_t}{(1+\gamma)L_{t-1}}\right) \; + \; (-\delta)\beta\mu \; \log\left(\frac{TAC_t}{ADV_t}\right) \\ 0 \; &= \; \alpha \; \log\left(\frac{TAC_t}{(1+\gamma)L_{t-1}}\right) \; + \; \beta \; \log\left(\frac{TAC_t}{ADV_t}\right) \end{aligned} \quad (8)$$

Solving for TAC_t gives the NBS:

$$TAC_t \; = \; (1+\gamma)^{\alpha} L_{t-1}^{\alpha} ADV_t^{\beta} \quad (9)$$

For equation (9) to be the minimum the second order condition (SOC) derived from (8) has to be positive.

$$\begin{aligned} \min_{TAC_t} \; \alpha \; \log\left(\frac{TAC_t}{(1+\gamma)L_{t-1}}\right) \; + \; \beta \; \log\left(\frac{TAC_t}{ADV_t}\right) \\ 0 \; \leqslant \; (\alpha \; + \; \beta)\frac{1}{TAC_t} \end{aligned} \quad (10)$$

Since $\alpha + \beta = 1$ the SOC is positive. Hence, equation (9) minimizes equation (6).

A.2 List of Fish Stocks in Data Set

Table 5: List of fish stocks in the data set including ID and fishing area.

ID	Fish species	Fishing Area (ICES Division)
1	Anchovy	VIII (Bay of Biscay)
2	Anchovy	IXa (Portuguese Waters)
3	Capelin	I, II (Barent Sea)
4	Capelin	V, XIV, IIa (Iceland-East Greenland-Jan Mayen Area)
5	Cod	22-24 (Baltic Sea)
6	Cod	25-32 (Baltic Sea)
7	Cod	IIIa, IV, VIId (Skagerrak, North Sea, Eastern Channel)
8	Cod	IIIa (Skagerrak)
9	Cod	IV (North Sea)
10	Cod	VIIe-k (Celtic Sea)
11	Cod	I, II (Barent Sea, Norwegian Sea)
12	Cod	Norwegian Waters
13	Cod	Va (Icelandic Waters)
14	Cod	VIIa (Irish Sea)
15	Cod	VIa (Celtic Sea and West of Scotland)
16	Haddock	IIIa, IV (Skagerrak, North Sea)
17	Haddock	IIIa (Skagerrak)
18	Haddock	IV (North Sea)
19	Haddock	VIa (West of Scotland)
20	Haddock	VIIb-k (Celtic Sea and West of Scotland)
21	Haddock	Arctic waters
22	Haddock	Va (Icelandic Waters)
23	Haddock	VIIa (Irish Sea)
24	Haddock	VIb (Rockall)
25	Herring	25 - 29, 32 (Baltic Sea excluding Gulf of Riga)
26	Herring	30 (Baltic Sea, Bothnian Sea)
27	Herring	31 (Baltic Sea, Bothnian Bay)
28	Herring	IIIa, 22 - 24 (Western Baltic Sea)

29	Herring	IIIa, IV, VIId (Skagerrak, Kattegat, North Sea, Eastern Channel)
30	Herring	VIIa, VIIg,h,j,k (Celtic Sea and South of Ireland)
31	Herring	VIa, VIIb,c (West of Scotland, Rockall)
32	Herring	VIIa (Irish Sea)
33	Herring	I, II, V, IVa, XIV (Norwegian Waters)
34	Herring	28.1 (Baltic Sea, Gulf of Riga)
35	Herring	Va (Icelandic Waters)
36	Herring	VIa (West of Scotland)
37	Hake	IIIa, IV, VI, VII, VIIIa,b (Skagerrak, Kattegat, North Sea, Irish and Celtic Sea, Channel, Bay of Biscay)
38	Hake	VIIIc, IXa, (Bay of Biscay, Portuguese Waters)
39	Horse Mackerel	IXa (Portuguese Waters)
40	Horse Mackerel	IIa, IVa, Vb, VIa, VII a-c, e-k, VIII (Norwegian waters, North Sea, Icelandic waters, West of Scotland, Irish Sea, Bay of Biscay)
41	Mackerel	North-east Atlantic
42	Megrim	IVa, VIa (North Sea, West of Scotland)
43	Megrim	VIb (Rockall)
44	Megrim	VIIIc, IXa (Bay of Biscay, Portuguese Waters)
45	Norway pout	IV, IIIa (Skagerrak, Kattegat, North Sea)
46	Plaice	21 - 23 (Kattegat, Belts, Sounds, Baltic Sea)
47	Plaice	VIIh-k (South-west of Ireland)
48	Plaice	VIIf,g (Celtic Sea)
49	Plaice	VIId,e (Eastern and Western Channel)
50	Plaice	VIIa (Irish Sea)
51	Plaice	IV (North Sea)
52	Plaice	20 (Skagerrak, Baltic Sea)
53	Saithe	IIIa, IV, VI (Skagerrak, North Sea, West of Scotland and Rockall)
54	Saithe	IIIa, IV (Skagerrak, Kattegat, North Sea)
55	Saithe	VI (West of Scotland)
56	Saithe	I, II (North-east Arctic)
57	Sandeel	IIIa, IV (Kattegat, Skagerrak, North Sea)
58	Sole	VIIh-k (South-west of Ireland)
59	Sole	VIIIa, b (Bay of Biscay)
60	Sole	VIIf,g (Celtic Sea)
61	Sole	VIId (Eastern Channel)
62	Sole	VIIe (Western Channel)

63	Sole	VIIa (Irish Sea)
64	Sole	IIIa, 22 - 24 (Baltic Sea, Skagerrak, Kattegat, Belts)
65	Sole	IV (North Sea)
66	Sprat	22 - 32 (Baltic Sea)
67	Sprat	IIIa (Skagerrak, Kattegat)
68	Blue whiting	I-IX, XII, XIV (North-east Atlantic)
69	Whiting	IV, VIId (North Sea, Eastern Channel)
70	Whiting	IV (North Sea)
71	Whiting	VIId (Eastern Channel)
72	Whiting	VIIe-k (South-west of Ireland)
73	Whiting	VIa (West of Scotland)

A.3 Constrained Regression of the whole Data Set

Table 6: Results of constrained estimation of equation (5) for the whole data set controlling for intra-group correlation and including stock effects. The reference stock is anchovy in the Bay of Biscay.

Variable	Coef.	SE	P>|t|	95% Conf.	Interval
$\log L_{t-1}$	.5350624	.0776168	0.000	.382771	.6873537
$\log ADV_t$	.4649376	.0776168	0.000	.3126463	.617229
c	.2449405	.005666	0.000	.2338232	.2560577
id					
2	-.0178775	.001009	0.000	-.0198573	-.0158977
3	-.0740927	.028757	0.010	-.1305167	-.0176687
4	-.2031885	.0035995	0.000	-.2102511	-.196126
5	.1172073	.0028473	0.000	.1116206	.1227939
6	-.0964518	.0043207	0.000	-.1049293	-.0879742
7	-.2650731	.0086931	0.000	-.2821297	-.2480164
8	-.2628518	.0181956	0.000	-.2985533	-.2271503
9	-.2441614	.0073908	0.000	-.2586629	-.2296598
10	.006073	.0086931	0.485	-.0109836	.0231297
11	-.2283687	.0032002	0.000	-.2346478	-.2220896
12	.0047488	.0282267	0.866	-.0506345	.0601321
13	-.2587948	.0002329	0.000	-.2592517	-.2583379
14	-.1659708	.0043077	0.000	-.174423	-.1575186
15	-.1467975	.007089	0.000	-.1607068	-.1328882
16	-.2008603	.0190897	0.000	-.238316	-.1634046

17	-.0758722	.0049869	0.000	-.085657	-.0660875
18	-.2951074	.0036965	0.000	-.3023602	-.2878545
19	-.2090788	.0005433	0.000	-.2101448	-.2080127
20	-.1946458	.0010608	0.000	-.1967272	-.1925645
21	-.21737	.0025937	0.000	-.2224591	-.2122809
22	-.2412691	.0035763	0.000	-.2482862	-.234252
23	-.0675602	.0077728	0.000	-.0828111	-.0523093
24	-.1914871	.0409817	0.000	-.271897	-.1110773
25	-.05491	.0057335	0.000	-.0661597	-.0436603
26	-.0685089	.0093621	0.000	-.0868781	-.0501396
27	1.062836	.0095986	0.000	1.044003	1.081669
28	-.0665689	.0294685	0.024	-.1243889	-.0087489
29	-.2906864	.003648	0.000	-.2978441	-.2835288
30	-.2196767	.0040361	0.000	-.2275958	-.2117576
31	-.3054405	.0041791	0.000	-.3136402	-.2972408
32	-.1560532	.0105818	0.000	-.1768156	-.1352908
33	-.2310716	.0042689	0.000	-.2394476	-.2226956
34	-.2091908	.0053132	0.000	-.2196158	-.1987657
35	-.2348795	.0049496	0.000	-.244591	-.225168
36	-.2491084	.0066595	0.000	-.262175	-.2360418
37	-.1879686	.0010373	0.000	-.1900038	-.1859334
38	-.1393376	.0102939	0.000	-.1595352	-.1191399
39	-.0188957	.0180847	0.296	-.0543796	.0165881
40	-.2894597	.0026778	0.000	-.2947137	-.2842056
41	-.2293509	.0034054	0.000	-.2360327	-.2226691
42	.0525507	.0102584	0.000	.0324229	.0726786
43	.3116574	.0599331	0.000	.194063	.4292517
44	-.0064534	.0050839	0.205	-.0164285	.0035217
45	.0849844	.0571519	0.137	-.0271529	.1971216
46	-.553943	.050445	0.000	-.6529207	-.4549653
47	-.0099536	.0125545	0.428	-.0345868	.0146795
48	-.1939818	.0032803	0.000	-.2004181	-.1875455
49	-.1940559	.0057501	0.000	-.2053381	-.1827736
50	-.1848394	.0232142	0.000	-.2303877	-.139291
51	-.1989675	.0044512	0.000	-.2077011	-.1902339
52	-.2175621	.0168906	0.000	-.2507031	-.1844212
53	-.2008574	.0093916	0.000	-.2192846	-.1824301
54	-.206577	.0100126	0.000	-.2262226	-.1869314
55	-.1253657	.0137805	0.000	-.1524044	-.0983271
56	-.2327649	.0051693	0.000	-.2429075	-.2226223
57	-.6092792	.0403349	0.000	-.68842	-.5301385
58	-.0364307	.0023673	0.000	-.0410755	-.0317858
59	-.2337443	.0009351	0.000	-.235579	-.2319095

60	-.2319759	.0021227	0.000	-.2361408	-.2278111
61	-.2165478	.0065353	0.000	-.2293707	-.2037248
62	-.2327536	.0106673	0.000	-.2536837	-.2118234
63	-.2277896	.0004657	0.000	-.2287034	-.2268759
64	-.1977565	.0052575	0.000	-.2080723	-.1874408
65	-.2368862	.0009159	0.000	-.2386832	-.2350892
66	-.1400078	.0040078	0.000	-.1478715	-.132144
67	.0518483	.0538994	0.336	-.0539072	.1576038
68	-.2244278	.0012489	0.000	-.2268783	-.2219773
69	.0319723	.0167115	0.056	-.0008172	.0647618
70	-.2495671	.0053667	0.000	-.260097	-.2390373
71	.3369272	.0171792	0.000	.3032201	.3706343
72	.0209455	.003441	0.000	.0141939	.0276971
73	-.1454601	.0122635	0.000	-.1695222	-.1213981
No. of obs.	1190				
F(1,1116)	47.52				
Prob > F	0.0000				
Root MSE	0.1429				

A.4 Constrained Regression of Data Subsets according to Data Quality

Table 7: Results of constrained estimation of equation (5) for the data subset 'poor data' controlling for intra-group correlation and including stock effects.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.709936	.0908189	0.000	.5304362	.8894359
$\log ADV_t$	.290064	.0908189	0.002	.1105641	.4695638
c	.1259883	.0116853	0.000	.1028927	.1490839
id					
23	.0561386	.0141504	0.000	.0281708	.0841063
27	1.190649	.0162868	0.000	1.158458	1.222839
43	.5528754	.0751829	0.000	.4042794	.7014713
46	-.3341022	.0640809	0.000	-.4607554	-.2074489
47	.1245186	.0197455	0.000	.0854923	.1635448
48	-.0951861	.0012173	0.000	-.097592	-.0927802
49	-.1008247	.0016726	0.000	-.1041305	-.0975189
50	-.0263505	.0322183	0.415	-.0900287	.0373276
52	-.0733206	.0248192	0.004	-.1223746	-.0242665

58	.0750894	.0078255	0.000	.0596225	.0905563
No. of obs.	157				
F(1,186)	61.11				
Prob > F	0.0000				
Root MSE	0.1549				

Table 8: Results of constrained estimation of equation (5) for the data subsets 'good data' controlling for intra-group correlation and including stock effects.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.5145598	.0853384	0.000	.3470906	.6820289
$\log ADV_t$	.4854402	.0853384	0.000	.3179711	.6529094
c	.2464371	.0062297	0.000	.2342119	.2586624
id					
2	-.018144	.0011094	0.000	-.0203211	-.0159669
3	-.0816889	.0316179	0.010	-.1437362	-.0196416
4	-.2022377	.0039576	0.000	-.2100041	-.1944713
5	.1164551	.0031306	0.000	.1103117	.1225986
7	-.2673693	.0095579	0.000	-.2861259	-.2486128
8	-.2676582	.0200058	0.000	-.3069178	-.2283986
9	-.2461137	.0081261	0.000	-.2620605	-.2301669
10	.0083693	.0095579	0.381	-.0103872	.0271259
11	-.2275234	.0035186	0.000	-.2344283	-.2206185
12	.0122049	.0310347	0.694	-.0486981	.0731078
13	-.2588563	.000256	0.000	-.2593587	-.2583539
14	-.1671087	.0047363	0.000	-.1764032	-.1578142
15	-.1486701	.0077942	0.000	-.1639656	-.1333746
16	-.1958177	.0209887	0.000	-.2370063	-.1546292
17	-.0771895	.005483	0.000	-.0879494	-.0664296
18	-.2941309	.0040642	0.000	-.3021067	-.2861552
19	-.2089353	.0005974	0.000	-.2101075	-.207763
20	-.1943656	.0011663	0.000	-.1966544	-.1920769
21	-.2180551	.0028517	0.000	-.2236514	-.2124589
22	-.2422138	.0039321	0.000	-.2499302	-.2344973
24	-.2023125	.0450587	0.000	-.2907362	-.1138888
25	-.0564246	.0063039	0.000	-.0687954	-.0440537
26	-.0709819	.0102934	0.000	-.0911819	-.0507819
28	-.0743531	.0324001	0.022	-.1379355	-.0107706
29	-.2897228	.0040109	0.000	-.2975939	-.2818518
30	-.2207428	.0044376	0.000	-.2294512	-.2120344
31	-.3043366	.0045948	0.000	-.3133535	-.2953197

32	-.1588484	.0116345	0.000	-.18168	-.1360168
33	-.2321992	.0046936	0.000	-.24141	-.2229884
34	-.2105943	.0058418	0.000	-.2220583	-.1991302
35	-.2361869	.005442	0.000	-.2468663	-.2255076
36	-.2473493	.007322	0.000	-.2617181	-.2329804
37	-.1876946	.0011404	0.000	-.1899326	-.1854566
38	-.1366184	.011318	0.000	-.158829	-.1144078
39	-.0236728	.0198838	0.234	-.0626932	.0153475
40	-.2887523	.0029442	0.000	-.29453	-.2829746
41	-.2284513	.0037442	0.000	-.235799	-.2211036
42	.049841	.0112789	0.000	.0277071	.0719748
44	-.0077963	.0055897	0.163	-.0187656	.0031729
45	.0698876	.0628375	0.266	-.0534255	.1932007
51	-.2001433	.004894	0.000	-.2097473	-.1905393
53	-.2033382	.0103259	0.000	-.223602	-.1830744
54	-.2092219	.0110086	0.000	-.2308254	-.1876183
55	-.1290059	.0151514	0.000	-.1587393	-.0992725
56	-.2341303	.0056835	0.000	-.2452838	-.2229769
57	-.6199337	.0443475	0.000	-.7069619	-.5329056
59	-.2339913	.0010281	0.000	-.2360089	-.2319737
60	-.2325366	.0023338	0.000	-.2371165	-.2279567
61	-.2182741	.0071855	0.000	-.232375	-.2041732
62	-.2299358	.0117285	0.000	-.2529519	-.2069197
63	-.2279126	.000512	0.000	-.2289174	-.2269078
64	-.1991453	.0057806	0.000	-.2104892	-.1878015
65	-.2371281	.001007	0.000	-.2391043	-.235152
66	-.1410664	.0044066	0.000	-.1497139	-.132419
67	.0376107	.0592614	0.526	-.0786847	.153906
68	-.2240979	.0013732	0.000	-.2267927	-.2214032
69	.0275579	.018374	0.134	-.0084995	.0636153
70	-.2481495	.0059005	0.000	-.2597288	-.2365702
71	.3323893	.0188882	0.000	.2953228	.3694558
72	.0218544	.0037833	0.000	.01443	.0292789
73	-.1486996	.0134835	0.000	-.1751597	-.1222394
No. of obs.	1033				
F(1,186)	36.36				
Prob > F	0.0000				
Root MSE	0.1402				

A.5 Constrained Regression by Fishing Area

Table 9: Results of constrained estimation of equation (5) for the Baltic Sea.

Variable	Coef.	SE	P>|t|	95% Conf.	Interval
$\log L_{t-1}$	.6993636	.064474	0.000	.5721692	.8265579
$\log ADV_t$	.3006364	.064474	0.000	.1734421	.4278308
c	.356181	.0023414	0.000	.3515618	.3608001
id					
6	-.2288324	.0059542	0.000	-.2405788	-.2170859
25	-.1660077	.0023975	0.000	-.1707375	-.1612779
26	-.1719255	.0054116	0.000	-.1826016	-.1612495
27	.9599202	.0056081	0.000	.9488565	.9709839
28	-.1274237	.0221135	0.000	-.1710491	-.0837983
34	-.3211781	.0020484	0.000	-.3252191	-.3171371
46	-.5703943	.039538	0.000	-.6483949	-.4923938
52	-.3050422	.0116654	0.000	-.3280556	-.2820287
64	-.3098618	.0020021	0.000	-.3138115	-.3059121
66	-.2547584	.000964	0.000	-.2566602	-.2528565
67	.0427092	.0424074	0.315	-.0409521	.1263706
No. of obs.	199				
F(1,186)	117.66				
Prob > F	0.0000				
Root MSE	0.1816				

Table 10: Results of constrained estimation of equation (5) for the North Sea.

Variable	Coef.	SE	P>|t|	95% Conf.	Interval
$\log L_{t-1}$	.5625783	.1186136	0.000	.3292719	.7958848
$\log ADV_t$	.4374217	.1186136	0.000	.2041152	.6707281
c	-.0190595	.0046259	0.000	-.0281584	-.0099605
id					
8	.00559	.0145217	0.701	-.0229734	.0341534
9	.02045	.0019901	0.000	.0165357	.0243644
16	.0543635	.0424574	0.201	-.0291479	.1378749
17	.1878869	.0056638	0.000	.1767466	.1990273
18	-.0344266	.0189337	0.070	-.0716681	.002815
19	.0527199	.014115	0.000	.0249564	.0804833
29	-.0299884	.0188595	0.113	-.0670841	.0071073
36	.010522	.0234618	0.654	-.035626	.05667
45	.3672366	.0740544	0.000	.2215756	.5128975
49	.0658969	.022072	0.003	.0224825	.1093114
51	.0646017	.0064825	0.000	.051851	.0773524

53	.0644633	.0010675	0.000	.0623635	.0665631
54	.0589638	.0020164	0.000	.0549976	.06293
55	.1415109	.0077746	0.000	.1262187	.1568031
57	-.3329888	.0483548	0.000	-.4281001	-.2378775
61	.0477603	.0032975	0.000	.0412744	.0542463
62	.025456	.0295864	0.390	-.0327387	.0836508
65	.0254297	.0118851	0.033	.0020524	.048807
70	.0105216	.021486	0.625	-.0317402	.0527834
71	.6050087	.0129684	0.000	.5795005	.6305168
72	.2817169	.0185433	0.000	.2452433	.3181905
No. of obs.	364				
F(1,341)	22.50				
Prob > F	0.0000				
Root MSE	0.1254				

Table 11: Results of constrained estimation of equation (5) for the Celtic Sea and West of Scotland.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.5598545	.0898339	0.000	.3828795	.7368295
$\log ADV_t$	.4401455	.0898339	0.000	.2631705	.6171205
c	.246427	.0166193	0.000	.2136866	.2791673
id					
14	-.1678912	.0150472	0.000	-.1975345	-.1382479
15	-.1478295	.0182662	0.000	-.1838144	-.1118446
20	-.198281	.0088337	0.000	-.2156835	-.1808785
23	-.0683737	.0190576	0.000	-.1059177	-.0308298
24	-.1816932	.0574937	0.002	-.2949572	-.0684292
30	-.2216838	.0147328	0.000	-.2507077	-.1926599
31	-.3100717	.0052246	0.000	-.3203642	-.2997792
32	-.1559695	.0223088	0.000	-.1999183	-.1120208
42	.0525311	.0219345	0.017	.0093197	.0957425
43	.3275047	.0794282	0.000	.1710293	.4839801
47	-.0092398	.024592	0.707	-.0576868	.0392071
48	-.1983259	.0062647	0.000	-.2106676	-.1859843
50	-.1807207	.0369296	0.000	-.2534728	-.1079686
58	-.0389708	.0128013	0.003	-.0641898	-.0137519
60	-.2345942	.0125182	0.000	-.2592553	-.2099332
63	-.2309372	.0106004	0.000	-.2518202	-.2100541
69	.0340139	.0294033	0.249	-.0239114	.0919392
73	-.1448393	.0242552	0.000	-.1926226	-.0970561

No. of obs.	257
F(1,237)	38.84
Prob > F	0.0000
Root MSE	0.1149

Table 12: Results of constrained estimation of equation (5) for the Bay of Biscay and Atlantic Iberian Waters.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.6371275	.1223089	0.000	.394176	.8800791
$\log ADV_t$	.3628725	.1223089	0.004	.1199209	.605824
c	.2374897	.0089285	0.000	.2197542	.2552252
id					
2	-.0165506	.00159	0.000	-.019709	-.0133923
38	-.152874	.0162212	0.000	-.1850954	-.1206525
39	.0048854	.028498	0.864	-.0517223	.0614931
44	.0002319	.0080112	0.977	-.0156815	.0161452
59	-.2325146	.0014735	0.000	-.2354416	-.2295876
No. of obs.	98				
F(1,91)	27.14				
Prob > F	0.0000				
Root MSE	0.1547				

Table 13: Results of constrained estimation of equation (5) for the Non-EU waters (Barent Sea, Icelandic Sea, Norwegian Sea and East Greenland Sea).

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.1680581	.1159867	0.149	-.0603473	.3964635
$\log ADV_t$	.8319419	.1159867	0.000	.6035365	1.060347
c	.061664	.0345061	0.075	-.0062867	.1296146
id					
4	.0238991	.048352	0.622	-.0713175	.1191156
11	-.0031691	.0477553	0.947	-.0972106	.0908725
12	.3482838	.0851536	0.000	.1805961	.5159714
13	-.049828	.0426251	0.243	-.133767	.034111
21	-.0195663	.0390972	0.617	-.0965579	.0574254
22	-.0481117	.0376288	0.202	-.1222117	.0259883
33	-.041189	.0365938	0.261	-.113251	.0308729

35	-.0482153	.0355767	0.177	-.1182743	.0218437
37	.0270038	.0445231	0.545	-.0606728	.1146804
40	-.0667302	.0469746	0.157	-.1592344	.025774
41	-.0031808	.048062	0.947	-.0978263	.0914647
56	-.0471395	.0352484	0.182	-.116552	.0222729
68	-.0084546	.0448394	0.851	-.0967541	.0798449
No. of obs.	272				
F(1,257)	2.10				
Prob > F	0.0000				
Root MSE	0.1274				

A.6 Unconstrained Regression of the whole Data Set

Table 14: Results of unconstrained estimation of equation (5) for the whole data set controlling for intra-group correlation and including time effects.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.3307729	.0660434	0.000	.1991177	.462428
$\log ADV_t$	.3384203	.0503443	0.000	.2380607	.4387799
c	1.593199	.2961489	0.000	1.002837	2.183561
year					
1989	-.0184941	.0199377	0.357	-.0582391	.0212509
1990	-.0237399	.0267915	0.379	-.0771478	.029668
1991	-.0107436	.0271368	0.693	-.0648398	.0433526
1992	-.0130753	.0246696	0.598	-.0622532	.0361026
1993	.0113228	.0244916	0.645	-.0375003	.060146
1994	.0088143	.0260903	0.736	-.0431958	.0608244
1995	-.0057616	.022727	0.801	-.0510672	.0395439
1996	-.0273017	.0263191	0.303	-.0797678	.0251644
1997	-.0046693	.0273199	0.865	-.0591305	.049792
1998	.020071	.0266997	0.455	-.0331539	.073296
1999	-.0028923	.0255673	0.910	-.0538598	.0480752
2000	-.032633	.0262797	0.218	-.0850206	.0197546
2001	-.049235	.0282207	0.085	-.1054919	.0070218
2002	-.0785092	.0297701	0.010	-.1378548	-.0191637
2003	-.094106	.0311116	0.003	-.1561258	-.0320863
2004	-.0823423	.0356452	0.024	-.1533998	-.0112849
2005	-.0963131	.0366412	0.010	-.169356	-.0232702
2006	-.0793586	.0344197	0.024	-.147973	-.0107442
2007	-.0744907	.0343029	0.033	-.1428722	-.0061092

2008	-.0970396	.037756	0.012	-.1723049	-.0217743
2009	-.089637	.037479	0.019	-.1643499	-.014924
2010	-.1083645	.0376516	0.005	-.1834216	-.0333075
2011	-.1026436	.0493	0.041	-.2009214	-.0043658
2012	-.1239874	.0453305	0.008	-.2143522	-.0336227
2013	-.0794007	.0391103	0.046	-.1573657	-.0014357
No. of obs.	1190				
F(27,72)	2.10				
Prob > F	0.0000				
R^2 overall	0.9267				
ρ	0.8495				

A.7 Unconstrained Regression of Data Subsets according to Data Quality

Table 15: Results of unconstrained estimation of equation (5) for the data subset 'poor data' controlling for intra-group correlation and including stock effects.

Variable	Coef.	SE	P>|t|	95% Conf.	Interval
$\log L_{t-1}$	.4023689	.0883786	0.001	.2054492	.5992887
$\log ADV_t$	.1993705	.0792835	0.031	.0227159	.376025
c	1.600721	.3587873	0.001	.8012936	2.400149
No. of obs.	157				
F(2,10)	17.27				
Prob > F	0.0006				
R^2 overall	0.6845				
ρ	0.9332				

Table 16: Results of unconstrained estimation of equation (5) for the data subset 'good data' controlling for intra-group correlation and including stock effects.

Variable	Coef.	SE	P>|t|	95% Conf.	Interval
$\log L_{t-1}$	.3390246	.0748254	0.000	.189402	.4886473
$\log ADV_t$	.3686466	.0578955	0.000	.2528774	.4844159
c	1.440376	.3197201	0.000	.8010562	2.079696
year					
1989	-.0177212	.0211071	0.404	-.0599275	.0244851

1990	-.0241933	.0289741	0.407	-.0821305	.0337439
1991	-.0008961	.0282181	0.975	-.0573215	.0555294
1992	-.0012698	.0241792	0.958	-.0496191	.0470796
1993	.0233403	.025077	0.356	-.0268043	.0734849
1994	.0187905	.0261301	0.475	-.0334598	.0710407
1995	.0056933	.0216606	0.794	-.0376198	.0490065
1996	-.0150631	.0259426	0.564	-.0669386	.0368125
1997	-.0117718	.0255683	0.647	-.0628988	.0393552
1998	.01818	.0237936	0.448	-.0293983	.0657584
1999	.0119378	.0255813	0.642	-.0392152	.0630907
2000	-.0179682	.0262989	0.497	-.0705562	.0346197
2001	-.0369013	.0283612	0.198	-.093613	.0198105
2002	-.056332	.0295918	0.062	-.1155045	.0028404
2003	-.0782058	.0322074	0.018	-.1426085	-.013803
2004	-.0620502	.0361623	0.091	-.1343612	.0102608
2005	-.0771939	.0376634	0.045	-.1525065	-.0018813
2006	-.0651467	.0343827	0.063	-.1338992	.0036058
2007	-.0647033	.0342641	0.064	-.1332187	.0038121
2008	-.1027223	.0380986	0.009	-.178905	-.0265395
2009	-.0881473	.0380318	0.024	-.1641966	-.012098
2010	-.1110507	.0376822	0.005	-.186401	-.0357004
2011	-.1179011	.0491007	0.019	-.216084	-.0197182
2012	-.1234348	.0465101	0.010	-.2164374	-.0304321
2013	-.0851217	.0390891	0.033	-.1632852	-.0069581
No. of obs.	1033				
F(27,61)	24.92				
Prob > F	0.0000				
R^2 overall	0.9517				
ρ	0.7716				

A.8 Unconstrained Regression by Fishing Area

Table 17: Unconstrained estimation of equation (5) for the Baltic Sea.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.4888928	.1205582	0.002	.223546	.7542397
$\log ADV_t$	.2465183	.0629841	0.002	.1078913	.3851453
c	1.39892	.6065622	0.042	.0638858	2.733955
No. of obs.	199				
F(2,11)	15.56				
Prob > F	0.0006				
R^2 overall	0.7834				
ρ	0.8412				

Table 18: Unconstrained estimation of equation (5) for the North Sea.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.3945414	.1384688	0.010	.1065799	.682503
$\log ADV_t$	.3319185	.0700477	0.000	.1862463	.4775908
c	1.254464	.4583574	0.012	.3012577	2.20767
No. of obs.	364				
F(2,21)	45.88				
Prob > F	0.0000				
R^2 overall	0.9343				
ρ	0.7393				

Table 19: Unconstrained estimation of equation (5) for the Celtic Sea and West of Scotland.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.4098943	.0662733	0.000	.2706593	.5491293
$\log ADV_t$	.3299384	.0950112	0.003	.1303272	.5295496
c	1.026098	.2867483	0.002	.4236619	1.628534
No. of obs.	257				
F(2,18)	51.36				
Prob > F	0.0000				
R^2 overall	0.9121				
ρ	0.7576				

Table 20: Unconstrained estimation of equation (5) for the Bay of Biscay and Atlantic Iberian Waters.

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.2863142	.1214515	0.065	-.0258869	.5985153
$\log ADV_t$	.2187017	.1000668	0.081	-.0385282	.4759317
c	2.089289	.6022448	0.018	.5411695	3.637409
No. of obs.	98				
F(2,5)	5.34				
Prob > F	0.0573				
R^2 overall	0.8852				
ρ	0.7878				

Table 21: Unconstrained estimation of equation (5) for the Non-EU waters (Barent Sea, Icelandic Sea, Norwegian Sea and East Greenland Sea).

Variable	Coef.	SE	P>|t|	95% Conf. Interval	
$\log L_{t-1}$	.1422653	.0803429	0.100	-.0313051	.3158357
$\log ADV_t$	.7235338	.1172368	0.000	.470259	.9768086
c	.7474733	.3379954	0.046	.0172786	1.477668
No. of obs.	272				
F(2,13)	108.73				
Prob > F	0.0000				
R^2 overall	0.9146				
ρ	0.3353				

References

Bailey, M., Rashid Sumaila, U., Lindroos, M., 2010. Application of game theory to fisheries over three decades. Fisheries Research 102, 1–8.

Binmore, K., Rubinstein, A., Wolinsky, A., 1986. The nash bargaining solution in economic modelling. Journal of Economics 17, 176–188.

Churchill, R., Owen, D., 2010. The EC common fisheries policy, 1st Edition. Oxford University Press, Oxford.

Clark, C. W., 1990. Mathematical Bioeconomics, 2nd Edition. Wiley, New York.

European Commission, 2001. Green paper on the future of the common fisheries policy.

European Commission, 2009. Green paper on the reform of the common fisheries policy.

European Council, 2002. Council regulation (EC) No 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy.

European Council, 2014a. Council Regulation (EU) No 43/2014 fixing for 2014 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in Union waters and, to Union vessels, in certain non-Union waters.

European Council, 2014b. Draft Minutes of Fisheries Council Meetings.
URL `http://www.consilium.europa.eu/register/en/content/int/?lang=EN&typ=ADV`

European Union, 2013. Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, Amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and Repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.

European Union, 2015. Glossary.
URL http://europa.eu/legislation_summaries/glossary/qualified_majority_en.htm

Franchino, F., Rahming, A., 2003. Biased ministers, inefficiency and control in distributive policies: An application to the EU fisheries policy. European Union Politics 4, 11–36.

Froese, R., 2011. Fishery reform slips through the net. Nature 475.

Gordon, H., 1954. The economic theory of a common-property resource: The fishery. Journal of Political Economy 62, 124–142.

Hilborn, R., 2007. Defining success in fisheries and conflicts in objectives. Marine Policy 31, 153–158.

Hoffmann, J., Quaas, M., 2015. Common pool politics and inefficient fishery management. Journal of Environmental and Resource Economics.
URL http://link.springer.com/article/10.1007%2Fs10640-014-9842-4

ICES, 2014. Advice sheet.
URL http://ices.dk/publications/library/Pages/default.aspx

Kaitala, V., Lindroos, M., 2007. Game theoretic applications to fisheries. In: Weintraub, A., Romero, C., BjÃ¸rndal, T., Epstein, R., Miranda, J. (Eds.), Handbook Of Operations Research In Natural Resources. Vol. 99 of International Series In Operations Research amp; Mana. Springer US, pp. 201–215.

Khalilian, S., Froese, R., Proelss, A., Requate, T., 2010. Designed for failure: A critique of the Common Fisheries Policy of the European Union. Marine Policy 34, 1178–1182.

Leal, C., Quinones, R., Chavéz, C., 2010. What factors affect the decision making process when setting TACs?: The case of Chilean fisheries. Marine Policy 34, 1183–1195.

Lindroos, M., Kaitala, V., Kronbak, L. G., 2007. Coalition Games in Fisheries Economics. Blackwell Publishing Ltd, pp. 184–195.

Munro, G., 1979. The optimal management of transboundary renewable resources. Canadian Journal of Economics 12 (3), 355–376.

Nash, J., 1953. Two-person cooperative games. Econometrica 21, 128–140.

Okey, T., 2003. Membership of the eight Regional Fishery Management Councils in the United States: are special interests over-represented? Marine Policy 27, 193–206.

ORCA-EU, 2009. Survey of Institutions responsible for Inspecting Polish Fisheries in the Baltic Sea - Report. The Fisheries Secretariat (FISH), Stockholm, Sweden.

Quaas, M., Froese, R., Herwartz, H., Requate, T., Schmidt, J., Voss, R., 2012. Fishing industry borrows from natural capital at high shadow interest rates. Ecological Economics 82, 45 – 52.