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Analysis

A great fish war model with asymmetric players

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ABSTRACT

This paper analyzes the coalitional Great Fish War model under the assumption that players differ in their time preferences and use different discount rates. We derive the equilibrium payoffs of this coalitional game and investigate the impact of the asymmetry assumption on the extreme schemes of cooperative and non-cooperative equilibria. We then proceed to the computation of stable coalitions using time-consistent harvest-sharing policies for the partial coordination scheme, in the case where players are divided into two groups (high and low discount rates). We find that asymmetry has a significant impact on the way the resource is shared and on the profitability of coalitions. We also find that asymmetry is not a sufficient feature to overcome the puzzle of small coalitions.

1. Introduction

The Great Fish War model of Mirman (1979) is a parsimonious framework that has been extensively used for analyzing open-access problems in fisheries. A well known result is that the non-cooperative setting yields a Prisoner's Dilemma Type of result, and that coordination of international fisheries is Pareto-improving (Levhari and Mirman, 1980; Okuguchi, 1981), raising the issue of the stability of international coalitions.

Coordination in international fisheries has mainly been analyzed using a cooperative approach, comparing the full-coordination equilibrium with the no-cooperation equilibrium. The usual coordination instruments are trigger strategies (Benhabib and Radner, 1992; Cave, 1987; Hämäläinen et al., 1985), incentive strategies (Ehtamo and Hamalainen, 1993) and transfers (Mazalov and Rettieva, 2010; Pintassilgo et al., 2010).

Partial coordination in the management of fisheries, where a subset of countries agree to coordinate their use of the resource, occupies a middle ground between full cooperation and independent exploitation, and is more consistent with what can be observed in existing fishery management organizations.[1] Partial coordination has been analyzed using a non-cooperative approach (see Becker and Easter, 1999; Breton and Keoula, 2012; Kwon, 2006), requiring the cooperation agreement to be *self-enforcing*. As is the case in environmental games (Barrett, 1994) or in the cartel theory literature (d'Aspremont et al., 1983), stable large membership in partial coalitions cannot be obtained in the Great Fish War setting without the help of additional mechanisms, such as first-mover advantage (Kwon, 2006) or farsightedness (Breton and Keoula, 2012). Most partial coordination models assume that all players are identical, calling into question the role played by the symmetry assumption in the puzzle of small coalitions.[2]

One common source of asymmetry in the fishery economics literature is the marginal cost of fishing: the individual cost per unit of effort differs from one player to another. This kind of asymmetry is pervasive in analyses relying on textbook models like the basic one presented in Clark (1990). A recent example in an *M*-player setting is the coalitional fishery game of Pintassilgo et al. (2010) addressing the resilience of Regional Fishery Management Organizations.

Another important source of asymmetry in fisheries is the players' discount rates which are used to translate the different ways of evaluating the trade-off between immediate consumption and investment in the fish stock. However, the use of different discount rates raises the problem of how to aggregate them in a coalition. In a finite horizon setting, Gollier and Zeckhauser (2005) show that when individuals have heterogeneous constant rates of impatience, the group time preference will not be constant in general. In particular, exponential discounting yields a collective discount rate that decreases with the time horizon. Finding the cooperative equilibrium is then related to hyperbolic discounting (Laibson, 1997) and gives rise to a time-consistency

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[1] See for instance the Northwest Atlantic Fisheries Organization (NAFO — 12 members), the Western and Central Pacific Fisheries Commission (WCPFC — 25 members), and the International Commission for the Conservation of Atlantic Tunas (ICCAT — 47 members).

[2] In coalition games, the puzzle of small coalitions refers to the size of stable coalitions (maximum size of 2 or 3 players).

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problem (see Fujii and Karp, 2008 for a solution approach). Indeed, the cooperative solutions proposed by Munro (1979) and Plourde and Yeung (1989) are time inconsistent. Such "commitment solutions" see the share of the impatient player vanish over time, requiring a binding commitment by the players over an infinite horizon, which is not credible or politically feasible. Cooperative solutions of the Great Fish War with asymmetric players are derived in Houba et al. (2000) and Denisova and Garnaev (2008). Houba et al. (2000) solve a negotiation game between two players to find an acceptable sharing rule; and, Denisova and Garnaev (2008) analyze the cooperative solution for a coalition of M players under an equal sharing rule, without however addressing the question of coalition profitability.

This paper considers heterogeneous discount rates in a coalitional Great Fish War model involving M players. A first contribution is the characterization of profitable and Pareto-efficient time-consistent sharing rules among the members of a coalition. A second contribution is the derivation of the coalition versus fringe equilibrium strategies in an M-player Great Fish War coordination game, under both the simultaneous and sequential moves assumptions. Our results allow a comparison of the sizes of stable coalitions, steady-state stocks, catches and welfare under various scenarios.

The rest of the paper is organized as follows. Section 2 is a brief discussion of the assumption of the heterogeneity of discount rates in fisheries. The Great Fish War model and assumptions are recalled in Section 3. In Section 4, we derive non-cooperative, cooperative and partial coordination solutions with both simultaneous and sequential moves, for the general case of M asymmetric players. Coalitional stability is studied in Sections 5 and 6: Section 5 examines the profitability of the grand coalition and characterizes efficient and acceptable sharing rules. Section 6 studies the stability of partial coalitions for a special case where the fishery involves two types of players characterized by contrasting discount rates, under both the simultaneous and sequential moves assumptions. Section 7 is a conclusion.

2. Heterogeneous Discount Rates

This paper is based on a time-additive discounted utility model. The framework that serves as a reference for modeling intertemporal decisions using discounted utilities is the one popularized by Samuelson's (1937) work. It assumes the "same discount rate for all types of goods and all categories of intertemporal decisions."[3]

Because of renewed interest in discounting issues, especially in relation to the climate-change mitigation debate, there is a need to elaborate on the assumption of players that are heterogeneous in their discount rates. We start by the ubiquitous Ramsey Rule for discounting consumption, expressing the discount rate r as

$$r = \rho + gR(c)$$

where ρ is the social rate of pure time preference, g the growth rate of consumption over a given interval, c the per capita consumption and $R(c) = -c\frac{u''(c)}{u'(c)}$ the relative aversion to intertemporal inequality, u being the utility function.

In the fishery economics literature, differing discount rates have been interpreted as divergences in fishery management objectives. The higher the discount rate, the lower the proportion of biomass saved up for the following periods, and the higher the immediate consumption. In the particular case of the Great Fish War model used in this paper, the logarithmic utility function implies $R(c) = 1$ and the Ramsey rule boils down to:

$$r = \rho + g.$$

Hence, heterogeneity in the discount rates used by players (i.e. countries) in the Great Fish War models can be motivated by differences in their rates of time preference ρ or in their consumption growth rates g.

An example of a pure time preference motive ($r = \rho$) is provided in Vallée and Guillotreau (2010) in the context of the negotiation of access rights for European Union fleets to fish in the waters of the ACP (African, Caribbean, Pacific) countries. The authors consider both the possibility of higher preferences for the future by the ACP countries because of long-term ownership considerations, and the possibility of poor countries using high discount rates and showing short-term interest relative to their resources.

For the anticipated growth motive ($r = g$), Munro (1990) makes a case based on asymmetric access for a two-player setting referring to the Pacific Islands Tuna Fishery. He notes that due to a change in the fish runs, some of the islands found themselves in a much more favorable position to access to the resource, and thus placed greater emphasis on future returns than did the others. This translates into lower rates of discount in his model.

Clearly, divergent social discount rates may also be attributable to a mix of these two motives. Empirical evidence of a large variance in fishermen's personal discount rates is presented in Curtis (2002), where "Rates varied from as low as 0–10% to greater than 60% with the mode response in the 30–40% range[4]". Although these are not social, but personal discount rates, the paper makes the case that fish stock recovery programs design should take these into account in order to adequately incentivize commercial fishermen for voluntary participation, which will translate in diverging social discount rates among fishing countries. Another motivation for heterogeneous discount rates in a fishery is provided by Munro (1979): since there is a good deal of controversy over what constitutes the appropriate management objective of fisheries, there is no reason why managers would agree on a discount rate.

By construction, discount rates are subjective parameters. One of the problems in assessing players' management objective is the fact that social discount rates are generally not observable or common knowledge. Even if a disclosure is made in public evaluation guidelines (such as The Green Book in the UK for example), a country may use different social discount rates when appraising different projects (climate change mitigation, pollution control or management of fish stocks). Elicitation of social discount rates in fishery negotiations may be based on the eagerness of participating countries to protect the fishery. In an analysis of the Cod Fishery of the European Union and Russia in the Baltic Sea, Pietikäinen (2005) suggests that total catch limits proposed by each party reflect relative eagerness to protect the fishery. The paper also suggests that previous (non-cooperative) harvest shares may be used as an indicator of players' time preferences in order to design a cooperative scheme. One must however be careful since resulting diverging discount rates may stand in part for other types of asymmetries or uncertainties not explicitly modeled: differences in production costs, fishing costs or consumer preferences.

As already mentioned, discounting issues have become one the central topics of the climate change mitigation debate. In that literature, it is recommended, for ethical reasons, that the pure time preference rate ρ be close to zero, thus giving equal weights to the welfare of successive future generations. Good reviews on discounting issues in climate change economics are provided, for example, in Gollier (2010), Gollier (2012) and Scarborough (2011). The debate is also fostering a literature on zero discounting in resource and environmental management models. In that context, it is worthwhile mentioning that Nowak (2006, 2008) showed that the non-cooperative equilibrium solution in the Great Fish War model converges to an overtaking equilibrium when the players' discount rate vanishes, with higher values for the steady-state stock and consumption. This means that if agents would

[3] Frederick et al. (2002).

[4] Curtis (2002), page 776.