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Shared stocks, game theory and the zonal attachment principle

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ABSTRACT

The outcomes of a Nash-Cournot game and a game of cooperation supported by a threat strategy are compared. The discussion is related to the ongoing conflict over the mackerel stock in the Northeast Atlantic. Despite the absence of a comprehensive management agreement, the outcome of the mackerel fishery is nowhere near what is predicted by the Nash-Cournot equilibrium. To the contrary, the countries involved seem to be engaged in an informal cooperation, supported by an implicit threat of mutually assured destruction should any single one compete too aggressively. The zonal attachment principle of dividing the total catch from shared stocks is also examined and found wanting in many cases.

1. Introduction

Many fish stocks around the world migrate across international boundaries and are, therefore, shared among two or more nations. This is the case in particular in the Northeast Atlantic. The migratory pelagic stocks (herring, mackerel, blue whiting) traverse the economic zones of four countries (Iceland, Norway, the Faeroe Islands and the pre-Brexit EU) as well as the high seas in between.

Agreements on managing these stocks have been concluded between the countries concerned, but some of these have periodically broken down, due to changes in the migrations of the stocks involved. This happened with respect to the mackerel stock after it began to appear in the Icelandic economic zone in significant quantities in 2007. The agreement was partially restored in 2014, but Iceland and Greenland are still not part of it (in recent years mackerel has been encountered in the Greenlandic economic zone).

A situation where management agreements of shared stocks break down, or the absence of such agreements, calls for a game-theoretic analysis. For non-economists, "game theory" sounds frivolous, to the point of not deserving to be taken seriously. This is unfortunate, because game theory is a serious matter indeed, dealing with the strategic interaction among firms, individuals or countries where the outcome of decisions made by one agent depends on the decisions made by other agents, implying that one particular agent had better take into account what the others might do.[1]

Problems of strategic interaction can, however, be posed in several ways, and the outcome can be critically dependent on how the problem is framed. Two such approaches will be discussed in this paper. One is the Nash-Cournot game where each player takes decisions based on hypotheses about what other players will do. Assuming full information, it makes sense to look at an outcome where the hypothetical actions of all players are the best responses to what all others do. Despite the impeccable and appealing logic of this framework it can lead to extremely destructive competition which we do not typically see being realized.

The other approach is to assume that cooperation prevails and look for how it could be supported by threat strategies. The weakness of this approach is that it does not explain how cooperation came about in the first place. The fact that gains from abandoning cooperation are transient is what basically supports cooperation once it has been established; with a low enough discount rate and a suitably severe threat strategy, gains from cooperation will outweigh gains from defection.

The mackerel fishery, for one, seems to fit the latter scenario much better than the Nash-Cournot framework, despite the rhetoric about irresponsible behavior that the parties engage in from time to time. As Fig. 1 shows, both the fish landings and the stock have been growing most of the time since the dispute began, and the fishing mortality has not increased (Fig. 2). Even if the stock growth has undoubtedly been driven by advantageous environmental conditions, an aggressive Nash-Cournot behavior would have gone a long way towards destroying the stock (Hannesson, 2013a, 2013b, 2014).

In this paper we shall use a simple model to analyze the difference between the Nash-Cournot game and threat strategies designed to uphold a preexisting cooperation. It is not our purpose to model the mackerel fishery as such; this we have done elsewhere, as already noted. We nevertheless find it interesting and motivating to have the mackerel conflict in mind and so formulate our model as a highly stylized one of the mackerel fishery. We surmise that this may indeed be a

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[1] On game theory, see for example Gibbons (1992) and Tirole (1990).

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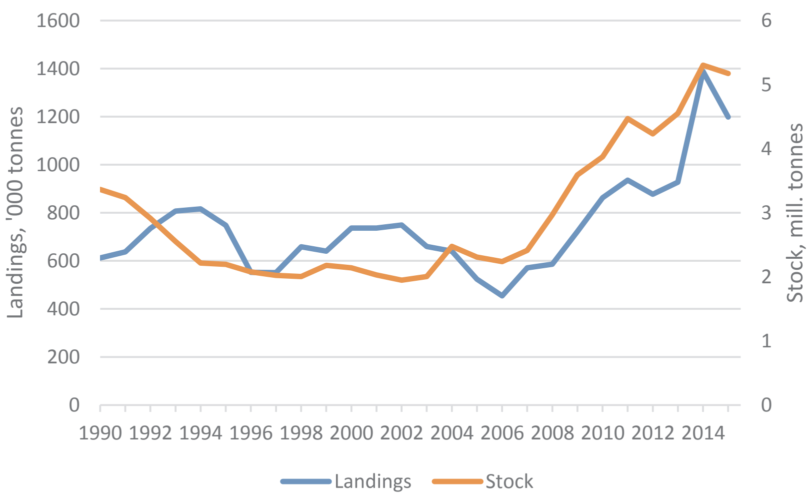

Fig. 1. Spawning stock and landings of Northeast Atlantic mackerel 1990–2015.
Source: ICES (2016).

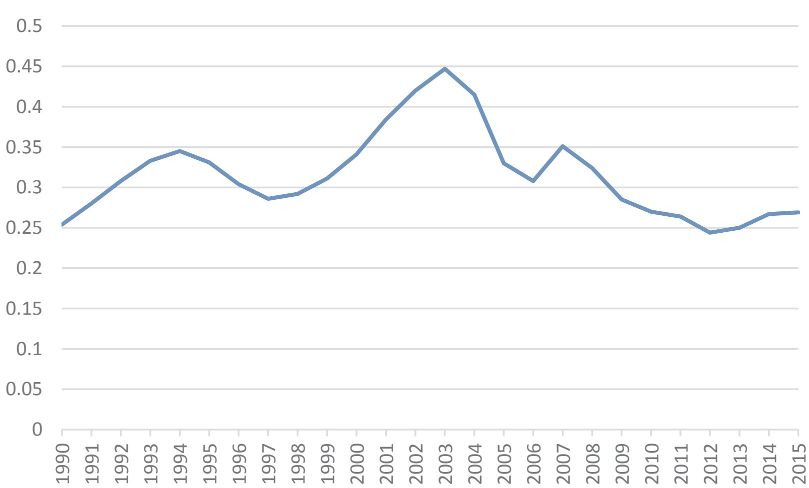

Fig. 2. Fishing mortality of Northeast Atlantic mackerel 1990–2015.
Source: ICES (2016).

suitable approach for many other migrating stocks.[2]

An additional purpose of this paper is to investigate the so-called "zonal attachment principle." It has been postulated that all that is needed to establish cooperation in management of shared stocks is to find out how much of the stock resides in each country's economic zone and distribute the total catch quota in the same way. As will be shown, this is not necessarily enough; small parties in particular may need to be brought on board with a larger share of the total catch quota than corresponds to their share of the stock.[3]

2. The Nash-Cournot equilibrium

Fig. 3 shows the geographic distribution of quarterly catches of mackerel. In the first quarter they are mainly concentrated in the spawning grounds west of the British isles. In the second quarter the stock begins to spread northwards to the economic zones of the Faeroe Islands, Norway and Iceland, and into the high seas between them. Most of the captures take place in the third quarter, and in the fourth quarter the stock is on its way back to the spawning grounds. In makes sense, therefore, to model the stock as appearing at the beginning of each fishing period in the economic zone of the individual countries and staying there until the fishing is over, whereafter it disappears and grows and breeds as one unit. Then, at the beginning of the next period, the process repeats itself. We shall not here consider variability in migrations such as have caused so much consternation in recent years; for this the reader is referred to Hannesson (2014).

A discrete time model for stock growth is

$$X_{t+1} = S_t + G(S_t) \tag{1}$$

where X_{t+1} is the stock emerging at the beginning of period $t+1$, S_t is the stock left after fishing in period t, and $G(S)$ is surplus growth.

For simplicity, we shall look at the fishery in a two-country setting, as this is sufficient to obtain the principal qualitative results we are interested in. One country (the major one) always gets a share $\beta \geq ½$ at the beginning of each period, with the other country (the minor one) getting the remainder 1–β. The present value (V) of the major country's (Country 1) fish catches at a constant net price of fish normalized to one is

$$V = \beta X_0 - S_1 + \frac{\beta(S_1 + \bar{S}_2 + G(S_1 + \bar{S}_2)) - S_1}{r} \tag{2}$$

where r is the discount rate and S_1 is the stock left after fishing by Country 1 (the major country). For the minor country we get an analogous formulation by substituting 1–β for β. We ignore stock-dependent costs of fish, as this is not germane for the results, but makes them more dramatic.[4] We put a bar over the stock variable left behind by the minor country to indicate that it is not under control by the major country, which needs to make its best guess about what the other country will do.From (2) and the analogous problem for the minor

[2] The model is similar to one first formulated by McKelvey (see, for example, Golubtsov and McKelvey, 2007) with Pacific salmon in mind.

[3] On the zonal attachment principle, see Engesæter (1993). An earlier critique is in Hannesson (2007).

[4] For a formulation with stock-dependent unit cost of fish, see Hannesson (2007).