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ABSTRACT

Game theory studies the strategic interactions between and among decision makers, players, through mathematical models called games. This paper presents an overview on the evolution of the application of game theory to fisheries economics. The first applications emerged in the late 1970s, focussing upon internationally shared fish stocks. This occurred in the context of the UN Third Conference on the Law of the Sea, and the 1982 UN Convention on the Law of the Sea. During the 1980s and early 1990s the application of game theory to fisheries focused mainly on transboundary fish stocks. Thereafter, the applications to straddling fish stocks developed significantly, through the use of coalition games. This was a consequence of the mismanagement of these stocks, and the management regime brought forth in response by the 1995 UN Fish Stocks Agreement. The application of game theory to the management of national/regional fisheries is a new research frontier, as it is still much underexplored, when compared to international fisheries. This paper also summarizes the main research developments of a set of nine papers selected for this special issue on Game Theory and Fisheries.

1. Introduction

This Special Issue owes its origin to a Special Session on Game Theory and Fisheries Economics at the 18th Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET) held in Aberdeen, Scotland, in July 2016. The Special Session was mounted in recognition of the growing importance of the theory of strategic interaction, game theory, to fisheries economics. So successful was the Special Session that it was felt that further steps should be promptly taken. The Special Issue of this journal is the result.

Several papers presented at the Special Session were, as hoped, revised and submitted for publication in this Special Issue. It was decided, however, that submissions should not be restricted to those participating in the IIFET Conference Special Session. All IIFET members, with an interest in game theory, were invited to make submissions.

A game theoretic situation, let us be reminded, is deemed to arise when the actions of one “individual” have a perceptible impact upon one or more “individuals”, leading to a strategic interaction between or among the “individuals”. The relevance of the theory of such strategic interaction, game theory, to the economics of fisheries management has evolved gradually over time.

1.1. Evolution of the application of game theory to fisheries economics: the role of international fisheries

While increasing recognition is now being given today to the importance of game theory in fisheries economics, such was not always the case. The origin of modern fisheries economics is commonly traced back to the publication of H. Scott Gordon’s seminal article, “The Economic Theory of a Common Property Resource: The Fishery” (Gordon, 1954). The year 2019 will mark the 65th anniversary of that article. Up until the 25th anniversary of the Gordon article, game theory played little or no role in fisheries economics. The year 2019 will also happen to mark the 40th anniversary of the first article on a fisheries economics topic explicitly employing game theory (Munro, 1979).

Why this lack of interest in game theory? The Gordon model contrasts a perfectly competitive fishing industry, under open access conditions, with that of a sole owner of the fishery. In either case, there is no strategic interaction, and thus no need for game theory. It is true that in the years, indeed decades, prior to the late 1970s, much of what regulation there was of fisheries was done at the international level, where there was an obvious strategic interaction among the states involved. Fisheries economists of the day, to the extent that they commented on the fisheries management at the international level, glossed over the strategic interaction. A possible reason for this paucity of interest in strategic interaction lies in the claim that, while the application of game theory to economics can be traced back to the mid-1940s, such application did not really take hold until the 1970s (see, for example, Bierman and Fernandez, 1993).

The primary event, triggering the introduction of game theory to fisheries economics, was the UN Third Conference on the Law of the Sea, 1973–1982, which had a revolutionary impact upon the management of world fisheries. The Conference brought forth the 1982 UN Convention on the Law of the Sea, which led, in turn, to the advent of the Exclusive Economic Zone (EEZ) regime. The negotiations over fishery issues in the Conference were all but completed by 1975, with the result that several coastal states, e.g. Canada, United States, implemented EEZs before 1982. In

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any event, it was estimated that, if the EEZ regime became universal, which it is close to being, the EEZs would encompass 90% of the commercially exploitable marine capture fishery resources (Munro et al., 2004).

The EEZ regime brought the management of internationally shared fishery resources to the fore, where an internationally shared fishery resource is deemed to be any fishery resource exploited by two or more fishing states (Munro et al., 2004). Most fishery resources prior to the Conference had, of course, been internationally shared, a fact, which had not aroused much interest. The EEZ regime made the management of internationally shared fishery resources an issue that was inescapable.

Due to the mobility of marine capture fishery resources, the typical coastal state was forced to recognize that some of the fishery resources within its EEZ would almost certainly move into the EEZs of one, or more neighbouring coastal states – transboundary stocks – and/or would cross the EEZ boundary into the adjacent high seas, where they would be subject to exploitation by distant water fishing states – straddling stocks.[1] It has been estimated that, under the EEZ regime, internationally shared fishery resources account for one third of the aforementioned commercially exploitable marine capture fishery resources (Munro et al., 2004). In the early days of the 1982 UN Convention on the Law of the Sea, it was thought, mistakenly, that, of the two, only transboundary stocks were truly important.[2]

If the coastal states of the world could not ignore the resource management problem posed by transboundary stocks, then neither could fisheries economists. Strategic interaction between or among the coastal states sharing a transboundary stock lies at the heart of the resource management problem. Fishery economists, investigating the economic management of these stocks, found themselves compelled to bring to bear both the theories of non-cooperative and of cooperative games. The first articles, employing game theory, on the economic management of transboundary stocks appeared in 1979 and 1980.[3]

It is impossible to emphasize too strongly that this application of game theory did not arise from economists skilled in game theory seizing the opportunity to display their prowess. It arose, rather, from economists being forced by the policy issue at hand to apply game theory and to seek, if necessary, assistance in so doing.

The period of the 1980s and early 1990s saw a series of refinements of and extensions to the game theoretic analysis of the economic management of transboundary stocks. Then, in the late 1980s, a new internationally shared fish stock management problem began to emerge.

The earlier view that straddling stocks are unimportant was revealed by the late 1980s to have been quite simply wrong. Case after case of resource mismanagement involving straddling stocks arose, mismanagement, which could not be ignored. The UN found itself compelled to convene another conference, popularly referred to as the UN Fish Stocks Conference, 1993–1995. The Conference brought forth what is popularly referred to as the UN Fish Stocks Agreement, designed to supplement the 1982 UN Convention on the Law of the Sea (Munro et al., 2004).

The UN Fish Stocks Agreement led to a new regime emerging, that of Regional Fisheries Management Organizations (RFMOs). A RFMO is designed to bring together relevant coastal and distant water fishing states for the management of a straddling stock, or a set of such stocks. Examples are provided by the Northwest Atlantic Fisheries Organization (NAFO) and the Western and Central Pacific Fisheries Commission (WCPFC).

The economic management of straddling stocks through RFMOs is an undertaking far more formidable than is the economic management of transboundary stocks. In attempting to analyse the economic management of straddling stocks, it was soon found that simple non-cooperative and cooperative game models are quite inadequate for the task at hand. Far more sophisticated game theory models are required, with partition function games models proving to be the most successful so far.[4] Much more remains to be done, e.g. analyzing the consequences of uncertainty, as evidenced by several of the articles in this Special Issue.

1.2. Game theory and the management of national/regional fisheries: the new frontier

With respect to fisheries, the UN Third Conference on the Law of the Sea did far more than make the management of internationally shared stocks an unavoidable issue. The Conference massively increased the importance of management of fishery resources at the national/regional level. Prior to the Conference, coastal state jurisdiction over fishery resources off the coastal state coast extended to a maximum of 12 nautical miles. With the coming of the EEZ regime, that jurisdiction was extended to 200 nautical miles.[5] This then raises the question of whether game theory has a role to play in the analysis of the economic management of fishery resources within the EEZ. The short answer is that, while game theory does indeed have a role to play, the application of game theory to the economics of fisheries management at the national/regional level lags far, far behind the application at the international level. With that being said, one of the articles to follow does in fact apply game theory at the national/regional level.

Fisheries management at the national/regional level has developed in stages, with the first being what is popularly referred to as Regulated Open Access (Wilen, 1985), in which the national resource manager restricts the season by season harvests in order to conserve the fishery resources, but places no limits on the number of vessels seeking to compete for shares of the restricted harvests. The economic analysis of Regulated Open Access legitimately continued with the H. Scott Gordon assumption that the relevant fishing industry is perfectly competitive. Once again, there was no strategic interaction, and thus no need for game theory.

Regulated Open Access was seen to lead to resource rent dissipation and excess fleet capacity. The response by the national resource managers was to attempt to limit the fleet size in any given fishery through the so called license limitation or limited entry schemes. With the number of vessels limited to a given fishery, the assumption that the relevant fishing industry is perfectly competitive ceases to be valid. Strategic interaction among fishers, vessel owners, becomes a distinct possibility.

Under the original limited entry schemes, the resource managers found it very difficult to control the true fishing capacity – the ability to catch fish – with control of the number of vessels proving to be markedly inadequate for that purpose. Furthermore, the vessels allowed into the fishery were virtually invited to compete for shares of the restricted harvest. One had the makings of a competitive fisher game, which came to be analysed by Wilen (1985). His analysis reveals an almost textbook example of a Prisoner's Dilemma game, in which competing vessel owners are driven to expand fishing capacity, even if all recognize that by so doing resource rent will be dissipated.

Disappointment with the original limited entry schemes has led to increasing emphasis being given to what the FAO of the UN refers to as

[1] One should also note, as of yet not of great importance, discrete high seas stocks, to be found exclusively in the remaining high seas.

[2] Recall that it was estimated that only 10% of the commercially exploitable marine capture fishery resource would be found in the remaining high seas.

[3] In addition to the Munro (1979) article, referenced earlier, there were articles by Clark (1980) and Levhari and Mirman (1980).

[4] See, for example, Pintassilgo (2003); and Pintassilgo et al. (2010).

[5] Approximately 370 km.