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The impact of precautionary quota constraints on the composition of multispecies harvest portfolios

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ABSTRACT

Multi species fisheries management requires managers to consider the impact of fishing activities on several species. Precautionary harvest quota restrictions for single species causes displaced effort to be redirected toward alternative species and single-species measures can therefore have a multi-species impact. Portfolio theory and the expected utility hypothesis is used to predict changes in fishers' targeting choices in the Hake–Monkfish–Megrim and Cod–Haddock–Whiting fisheries when species-specific hypothetical precautionary constraints are implemented. Results suggest that the utility maximising assumption in a mean variance optimisation framework gives a good approximation of fishers' objective function in these two fisheries. Changes in the species composition of fishers' optimal harvest portfolio (given implementation of the hypothetical precautionary measures) suggest significant displacement of fleet into alternative fisheries occurs when barriers to such alternation do not exist.

1. Introduction

In June 2013 the European Parliament and Council of Ministers agreed upon a new and reformed European Common Fisheries policy (CFP) to be implemented across all EU marine waters in January 2014. One outcome of the agreements is that quotas and the use of species' maximum sustainable yields (MSY) will remain the primary means by which Member States (MS) attempt to achieve sustainable fisheries. Political problems with this form of fisheries management and with maintaining the scientifically recommended MSY throughout the political process have been documented within the EU [8]. Despite these highlighted problems, the reforms indicate that the degree to which scientific recommendations of MSY are adhered to in practice will be far more binding than has been the case historically, such that by 2020, all stocks are to be managed at MSY. It is now clear that major changes to fishing quotas in European waters will occur in the next 6 years.

Further changes to the CFP include a banning of all discards and the adoption of multi-annual and multi-species planning. This means that the quantity of any fish stock that can be sustainably harvested will be determined on the basis of interaction with, and impacts upon, other species and marine habitats. If sustainable fisheries are to be attained, the impact of fishing for a single commercial species on other commercial species will be of great importance. It is foreseeable that in waters where the by-catch of biologically sensitive species is high, quotas for any target species in question will be set lower than their potential MSY level (had they been considered in isolation).

According to the European Commission, EU legislators will only define the general framework, the basic principles and standards and the overall targets of the CFP while Member States will themselves develop recommendations on the actual implementing measures [12]. National policy makers will thus be charged with the responsibility of deciding upon and implementing the medium term management initiatives that will achieve the overall targets of the CFP. In this new policy environment, when setting species' total allowable catches (TACs), fishery managers must pay particular attention to the multispecies impact of harvesting an individual species, not least, the impact on other commercial species within the fishery and in neighbouring fisheries.

Models assisting the management process that follows the reforms will need to assess the environmental and ecosystem impacts of commercial fishing activity. In addition, behavioural economic models have a role to play since they offer a framework for attempting to describe the response of fishermen to any policy changes. According to Fulton et al. [13], human behaviour, and in particular fisher behaviour, is almost never explicitly considered

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by fisheries scientists in the assessment and management process. They posit that the uncertainty generated by unexpected resource user behaviour is as critical as ecosystem and environmental uncertainty because it has unplanned consequences and leads to unintended management outcomes. Indeed, technical measures can lead to results which actually work directly against specific sustainability targets for which they are designed [27].

While behavioural models may be under utilised by fisheries scientists, empirical analyses on the socio-economic impacts of fisheries regulations are plentiful (e.g. Jentoft [19]; Nielsen [25]). Given the recent EU policy developments prioritising the by-catch issue and multispecies management, empirical analyses that have the potential for multispecies level analyses are desirable. This article presents a behavioural modelling approach based on financial portfolio theory and the expected utility hypothesis in an attempt to model the change in the harvest behaviour of a fishing fleet affected by precautionary quota constraints. The intent of the research is to demonstrate how the portfolio methodology could be employed by fishery managers to predict the likely behavioural responses of a fishing fleet to changing quota restrictions. While this process is useful in its own right, it also demonstrates the need for improved fishery data collection processes to implement such models successfully. The portfolio approach is based on the portfolio theory developed by Markowitz [23]. Markowitz's portfolio analysis is a mathematical tool to determine how to select the optimum proportion of assets in a portfolio for investment. The approach lends itself well to multispecies fishery analysis because given certain assumptions about the objective function of a fishing fleet it is possible to estimate changes in multispecies targeting behaviour given changes in single species harvest constraints. Thus a "multi-species-wide" impact of precautionary measures can be assessed. While portfolio theory has been extensively used for research into financial, agricultural and energy markets, its application to fisheries management and policy is rare. Some of the few papers that have done so are reviewed in the following section.

Section 2 discusses previous literature that applies portfolio theory to fishery economic issues. Section 3 then presents the theory underlying the portfolio approach and how it is applied in this study to the concept of mixed fisheries management. Section 4 provides a description of the multispecies Irish fishery investigated in the analysis and a brief description of the data used. The estimation results of alternative management scenarios are then presented in Section 5. The paper concludes with a discussion of its major findings and their implications for fisheries management.

2. Previous applications of portfolio theory within fisheries economics

While portfolio theory has been routinely applied in agricultural economics (e.g. [20,21]), empirical multi-species analysis usually follows one of two formats; a bio-economic model which determines the optimal harvest rate of more than one species using estimated predator–prey or competitor parameters, or structural ecosystem models that can be used to determine optimal TACs across multiple species. More recently however, portfolio theory has been applied to ecosystem management [5], and more specifically, fisheries management, due to its capacity to embody a multi-species perspective and directly incorporate risk. Hanna [16] advocates portfolio theory as a means of balancing fisher objectives and societal objectives while others extend this idea to "explicitly recognise fishery resources as risk-bearing capital assets that can provide society with benefits indefinitely" [10,11]. These studies focus on realigning the goals of individual fishers with societal goals by adopting property rights, incentive schemes and fishing restrictions such that ecosystem service payoffs (as opposed to commodity payoffs) can be delivered to society. Others see the portfolio approach as a means of protecting fishing communities from the risk of fluctuations in the abundance, availability, or price of individual species, where fishers choose among a diverse portfolio of harvestable resources rather than being forced by regulation to specialise in one or an extremely limited number of species [18].

Elsewhere, Yang et al. [34] use portfolio theory to assess the behaviour of New Zealand fishers' who face multiple targeting options to predict the optimal targeting strategies under a Quota Management System (QMS). Species considered by Yang et al. [34] were selected based on two criteria; the commercial value of the species and the availability of data. These two criteria were also highly relevant in this analysis of the Irish mixed fisheries and will be discussed further in Section 3.

Sanchirico et al. [29] also adapted financial portfolio theory as a method for ecosystem based fishery management (EBFM) that accounts for species interdependencies, uncertainty, and sustainability constraints. Illustrating the method with routinely collected species catch data available from Chesapeake Bay in the United States, the authors demonstrate the gains from taking into account species variances and covariances in setting species total allowable catches. They find over the period from 1962–2003 that managers could have increased the revenues from fishing and reduced the variance by employing ecosystem frontiers in setting catch levels. Sanchirico et al. [29] also point out that compared to structural models of the ecosystem, deriving ecosystem frontiers provides a complementary view that is simple to implement and flexible enough to accommodate different ecological, economic, and social objectives by including additional constraints or objective functions. However, they also point out that a limitation of ecosystem frontiers is that the policy prescriptions are only as good as the estimates of the means and covariances that characterize the multivariate stochastic process.

Elsewhere, [26] highlight the fact that fisheries regulations tend to be species specific but that species can be part of a multispecies fishery. Therefore since harvest rates are correlated, net revenues attributed to each species are also likely to be correlated. The authors contend that this correlation means that portfolio theory is well suited for multi-species fisheries that exhibit joint productive characteristics. The authors therefore used a portfolio approach to model the behaviour of fishermen faced with multiple targeting options in a random harvest fishery. The approach draws from the expected utility hypothesis and financial portfolio theory to predict optimal targeting strategies. The methodology was applied to the pelagic long line fleet operating in the U.S. Atlantic Ocean, Caribbean and Gulf of Mexico. Results from the model provide evidence that area closures aimed at reducing juvenile swordfish mortality will be more effective in certain regions. Efficient risk-return frontiers were also generated for use in predicting targeting behaviour in lieu of a closure. The frontiers suggested that trips that target swordfish exhibit a smaller degree of variability than trips that do not.

More recently, [32] uses a mean–variance portfolio optimisation approach to determine whether there is potential for fishers in Dominica to reduce the variability of net trip revenues. Their results suggested that fishers could attain their ex ante targets and that given the potential for trip-level harvest portfolios with a more efficient mean–variance profile, the variability of net trip revenues could be reduced.

We employ portfolio theory to combine a multispecies and precautionary approach under a single empirical framework and follow [26] by incorporating the expected utility hypothesis into the analysis. Through this approach, an attempt is made to predict