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Fluctuating quota and management costs under multiannual adjustment of fish quota

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ABSTRACT

North Sea fisheries are managed by the European Union (EU) through a system of annual quota. Due to uncertainty about future fish stocks, yearly revisions of these policies lead to fluctuation in quota, which in turn affects harvest and investment decisions of fishermen. Determination of quota requires high management costs in terms of obtaining information and negotiations between experts and policy makers. To reduce both quota fluctuation and management costs, the EU has proposed a system of multiannual quota. In this paper we study the effect of multiannual quota on quota volatility and resource rents, while accounting for management costs. We develop a bi-level stochastic dynamic programming model, where at level one, the EU determines the quota that maximizes resource rents. At level two, fishermen decide myopically on their harvest and investment levels, subject to the quota. Results show that policy makers can reduce quota volatility and improve resource rents from the fishery with multiannual quota. Important trade-offs are involved in the accomplishment of these objectives: fish stock and investments become more volatile, which leads to more overcapacity.

1. Introduction

Total Allowable Catches (TACs) of North Sea fish species are established on an annual basis as new catch and biological survey data become available. Annual adjustment of quota results in overcapacity for fishermen (Eisenack et al., 2006) and high management costs for the EU (Arnason, 2009).

Natural fluctuation in fish stock growth provides a challenge to management of fish species, often resulting in sub-optimal adjustment and annually fluctuating quota (Daw and Gray, 2005). Fishermen in return are confronted with unstable quota. As capital adjustment is costly, adjusting capital stock each year to the new required level is cumbersome. Due to irreversibility of investment in capital stock and with fishermen revealing short-term behavior, the result is often volatile investment (Charles, 1983) or even overcapacity (Eisenack et al., 2006).

Management costs, i.e. the costs of operating the quota management system, have been estimated at 78 million euro per year for 13 European countries (European Advisory System Evaluation, 2007). Studies that derive management costs on a country or species basis show that these costs range from 2.5% of harvest value, for North Sea herring, to 25% of harvest value for Iceland, Newfoundland and Norway (Hatcher and Pascoe, 1998; Millazo, 1998; Arnason et al., 2000; Wallis and Flaaten, 2003; Simmonds, 2007). Discussions about whether these management costs are relatively small compared to benefits (Arnason et al., 2000) or whether they represent a net economic loss (Arnason, 2009) are ongoing. This implies that management costs should not be ignored when adjusting quota such that they maximize resource rents (Arnason, 2009), where resource rents are defined as the difference between revenues from harvesting a fish stock and costs of the corresponding fishing effort. To the best of our knowledge, management costs have not been fully accounted for in the literature on optimal policies, meaning that there may be a sub-optimal balance between economic and biological objectives.

In the 2002 reform of the Common Fisheries Policy, a first step towards multiannual management plans was proposed to reduce the problem of fluctuating quota and high management costs. Given

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biological targets such as obtaining a specific reduced fishing mortality rate, annual changes in quota and effort are not to exceed a certain percentage (European Commission, 2009). Besides setting quota, multiannual management plans also provide measures such as closed areas, mesh size, gear, inspections, monitoring and effort management.

Let us consider one of the measures under multiannual management plans. This is a management system where the policy is to keep quota constant for multiple years, i.e. multiannual quota. On one hand, this allows fishermen to reduce capital volatility. In addition, fewer meetings between policy makers and scientists are required, which reduces management costs and potentially increases resource rents. On the other hand, policy makers are restricted in their options to adjust quota to new developments in the fish stock.

Studies that evaluate multiannual management plans include Karagiannakos (1996), Kell et al. (1999), Roel et al. (2004) and Kell et al. (2006). Kell et al. (1999) examine whether the fish stock remains above the assigned precautionary limit of biomass. It shows that multiannual management is more likely to speed-up recovery in the stock than annual management, which in turn may lead to less restricted harvest levels. The authors, however, provide no reason for this finding. A counter-argument is raised in Roel et al. (2004), who argue that multiannual management is less effective because of the higher risk of falling below the precautionary level. Another counter-argument in Roel et al. (2004) states that due to uncertainty in the future fish stock, it is impossible to achieve interannual stability of quota. Unless quota are kept at very conservative levels, fixation may be done at the cost of reducing sustainability of fish species (Kell et al., 2006). The consequence may be even greater fluctuation of quota and greater volatility in investment (Karagiannakos, 1996). While these studies are based on landing data (Kell et al., 1999) or stock and landing data (Roel et al., 2004; Kell et al., 2006), it remains unknown to what extent quota fluctuate between periods under multiannual management plans and whether results of the above mentioned studies hold when uncertainty and dynamics in biological and economic factors are incorporated. Also the reduction in variable management costs, which include costs for meetings between policy makers and scientists, needs to be accounted for. If investment costs increase because of greater volatility in quota, this may be offset by reduced management costs and may even have a positive effect on resource rents. To the best of our knowledge, there are no studies that look at the effect of multiannual management plans, including reduced management costs, on resource rents.

With respect to the objective of multiannual management plans to reduce quota fluctuation and management costs, we formulate two research questions: (i) do multiannual quota reduce fluctuation in quota? And (ii) do multiannual quota improve resource rents? With respect to fishermen, the subquestion that follows is whether investment becomes more or less volatile and if overcapacity is reduced or increased under multiannual quota.

We address these questions with a bi-level dynamic model that includes stochastic dynamics of the fish stock and dynamics of capital stock. At the first level, the EU determines the quota that maximizes resource rents. At the second level, fishermen operate under a system of restricted open access, which means that their harvest and investment decisions are subject to the quota that the EU determines at level one. We assume that fishermen behave myopically in their decisions on harvesting and adjusting the capital stock. The problem is written in a stochastic dynamic programming (SDP) framework and is solved with Value Function Iteration.

While Kell et al. (1999, 2006) and Roel et al. (2004) only study biological effects of multiannual quota and while Arnason et al. (2000) and Arnason (2009) question the implication of high management costs on resource rents, the contribution of this paper to the literature is that the problems of fluctuating quota and high management costs are addressed simultaneously. For illustration we apply the model to North Sea plaice, which is one of the main commercially exploited flatfish in the North Sea.

2. Methods

We present a bi-level stochastic dynamic programming (SDP) model that includes stochastic dynamics of the fish stock and dynamics of capital stock (van Dijk et al., 2012). At the first level, the EU determines the quota that maximizes resource rents. Quota may be fixed for multiple years, which are called multiannual quota. At the second level, myopic fishermen are subject to this quota and decide on their annual harvest and investment levels correspondingly.

2.1. Fishermen: myopic harvest and dynamic investment behavior under restricted open access

We first present the decisions at level two, i.e. fishermen behavior with respect to harvest and investment. The importance of accounting for fishermen behavior has been pointed out in Wise et al. (2012). In this model, it is assumed that fishermen are homogeneous and that they operate under restricted open access. This means that the fishery sector is restricted by a quota, while each individual fisherman maximizes his own profits. Fishermen will only stop fishing when rents have dissipated (Homans and Wilen, 1997). In our model, a Spence harvest function describes the interaction between harvest and effort: $h_t = x_t(1 - e^{-qE_t})$, where q is a catchability coefficient (Spence, 1973). Hence, the effort E_t needed to harvest h_t depends on fish stock x_t:

$$E(x_t, h_t) = \frac{1}{q} ln\left(\frac{x_t}{x_t - h_t}\right). \tag{1}$$

The open access fish stock, i.e. the level of fish stock below which it is not profitable to harvest (Clark, 2006), is derived by equating revenues ph_t and costs $C_t = c_E E_t + c_R R_t$ and then solving for $\hat{x} = x_t$. Here, p is a fixed price, c_E is the cost per unit of effort and c_R is the cost per unit of revenue that represents crew costs:

$$\hat{x} = \frac{c_E}{pq(1 - c_R)}. \tag{2}$$

In Conrad and Clark (1987), c_E/pq has been identified as the bioeconomic equilibrium escapement in the Spence model. At fish stock levels below $\hat{x}$ harvest is zero, so that in such a case a positive quota is not binding. We therefore assume that $h_t = 0$ if $x_t < \hat{x}$.

Under pure open access, harvest takes place for a fish stock $x_t > \hat{x}$. In that case, the level of harvest is given by $h_t = (x_t - \hat{x})^+$, where the operator $(y)^+ = \max\{0, y\}$. In restricted open access, however, fishermen are also confronted with quota Q_t, such that fishermen tend to harvest

$$\hat{h}_t = \min\{(x_t - \hat{x})^+, Q_t\}. \tag{3}$$

Harvest is also determined by the available capital stock, k_t. This means that fishermen cannot harvest more than what their capital stock allows. Given the Spence harvest function and substituting capital stock k_t for effort E_t, provides the following myopic harvest rule:

$$h_t = \min\{\hat{h}_t, x_t(1 - e^{-qk_t})\}. \tag{4}$$

Based on similar assumptions as above, myopic investment behavior is determined by currently available and desired capital stock. The investment in period t becomes available in the next period, $t+1$. The capital stock is set to the effort level required to harvest $\hat{h}_t$, so that $k_{t+1} = E(x_t, \hat{h}_t)$. Given the available depreciated capital