Optimal management of a stochastically varying population when policy adjustment is costly

Abstract

Ecological systems are dynamic and policies to manage them need to respond to that variation. However, policy adjustments will sometimes be costly, which means that fine-tuning a policy to track variability in the environment very tightly will only sometimes be worthwhile. We use a classic fisheries management question – how to manage a stochastically varying population using annually varying quotas in order to maximize profit - to examine how costs of policy adjustment change optimal management recommendations. Costs of policy adjustment (here changes in fishing quotas through time) could take different forms. For example, these costs may respond to the size of the change being implemented or there could be a fixed cost any time a quota change is made. We show how different forms of policy costs have contrasting implications for optimal policies. While some types of cost act to smooth out variation in quotas and stock sizes, as one might have expected, others can actually increase variation in stock sizes and quotas through time. We also show that the potential economic impact on the fishery of managers assuming policy adjustment costs are present when in fact they are absent is much smaller than the impact of managers assuming such costs are absent if they are present.

Introduction

Ecosystems are dynamic and exhibit rich patterns of variability in both time and space. In designing management policies for ecosystems, managers need to decide how much of that variation to respond to. Managers could try to track variations in ecosystem dynamics very closely by setting policies that are extremely responsive to the environment. Many theoretical studies that seek to identify optimal policies for exploited populations and communities adopt this approach and largely ignore the challenges that would be involved in implementing such recommendations (e.g., Reed 1979, Neubert 2003, Sethi et al. 2005, Halpern et al. 2011). However, the policy process can often be much more sluggish to respond to variations in ecosystem dynamics (Walters 1978, Armsworth et al. 2012). Moreover, stakeholders impacted by ecosystem management may prefer some stability and not want to deal with continually changing management recommendations (Biais 1995, Armsworth and Roughgarden 2003, Patterson 2007, Patterson & Resimont 2007, Sanchirico et al. 2008). In other words, whatever gains are available from fine-tuning a policy prescription to reflect environmental variation more closely should be traded off against potential costs associated with the more interventionist approach to management this would require.

To illustrate these concepts, Figure 1 show an example from fisheries management. On the left axis, the figure shows a time series for the estimated population size, represented as spawning stock biomass, of west Atlantic bluefin tuna (Thunnus thynnus, henceforth bluefin) from a recent stock assessment (ICCAT 20XX). On the right axis the figure also shows the catch quota for the stock that was set by the relevant management agency (ICCAT 20XX). Despite the estimated population size declining by XX% between YYYY and ZZZZ, the quota was not changed during this period. Instead, the quota only changed occasionally and in between times was left unaltered. Fishery management decisions regarding this species can be highly contentious (Safina 1998, Sissenwine et al. 1998, Porch 2005). Moreover, the stock is fished by fleets from many nations with quotas being set by a multilaterial management agency through a process of negotiation. As such, we might reasonably anticipate that for this species there could be substantial transaction costs involved in reaching agreement over any quota change, which could contribute to the observed quota stability. More generally, reviews by Biais (1995) and Patterson and Resimont (2007) document many cases where changes in catch quotas that a management agency set were more modest than changes that would be recommended just by considering variations in stock abundance.

We use a classic fisheries management question to examine how accounting for costs of policy adjustment can change optimal policies (see also Ludwig 1980, Feichtinger et al. 1994, Wirl 1999). We focus on how harvest quotas for a stochastically varying fish population can be chosen to maximize the net present value of a fishery. Our formulation and solution method largely follow Reed’s classic treatment on this question, a treatment repeated widely in bioeconomic textbooks. With his formulation, Reed showed that a constant escapement policy could be optimal under certain conditions. Such a policy involves choosing annual quotas that are perfectly responsive to recruitment variation in a fish stock. In poor recruitment years, the quota is set to zero and no fishing is allowed. But any time there is a good recruitment pulse, a quota is set that allows the fishery to exactly compensate through harvesting, thereby maintaining the optimal escapement level. However, in that analysis, Reed did not account for any costs of policy adjustment, which for such a responsive management strategy potentially could be large.

As the example in Figure 1 makes clear, management policies will rarely be as responsive as this constant escapement policy assumes. In this paper, we explore conditions under which this lack of responsiveness may be a rationale response on the part of managers. Specifically, we consider a case where managers seek to balance the benefits in terms of increased profits from fishing from more finely tracking recruitment variations with the growing costs associated with adjusting policies quickly to do so. The policy adjustment costs involved could reflect pure administrative transaction costs or preferences held by fishermen, fish processing plants or other stakeholders, for less variable quotas. In seeking to account for these policy adjustment costs, we recognize that we do not know just what functional form they should take and that it will require a lot of empirical work to estimate that. Therefore, we scope three candidate functional forms that represent different assumptions about how these costs operate to determine whether the results we obtain are sensitive to such differences.

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