Journal of Environmental Economics and Management 79 (2016) 189–207

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

Coalition formation in fisheries with potential regime shift

Steve Miller [a,*], Bruno Nkuiya [b]

[a] Department of Applied Economics, University of Minnesota, St. Paul, MN, USA
[b] University of Alberta, Edmonton, AB, Canada T6C 4G9

ARTICLE INFO

Article history:
Received 10 March 2015
Available online 3 June 2016

JEL classification:
Q22
Q54
C72

Keywords:
Regime shifts
Partial cooperation
Dynamic games
Renewable resources
Uncertainty

ABSTRACT

A system can undergo rapid regime shift in which the growth of natural resources suddenly and permanently declines. We examine how the threat of such a shift alters the strategic management of a common pool renewable resource. We consider exogenous and endogenous threats and examine their effects on both incentives to join a coalition and harvest decisions. We find that an exogenous threat of reduced resource growth may cause the coalition to grow in size, and, perhaps of most interest, we identify conditions under which members of the stable coalition reduce harvest while non-members increase harvest in response to the threat. In contrast, an exogenous threat of total stock collapse may destabilize coalitions, resulting in higher harvest from former members, but reduced harvest by non-members. When the threat of either type of shift is endogenous, the threat of regime shift can induce stable coalitions with more than two members. In particular, we identify cases in which the first best (full cooperation) is sustained as an equilibrium outcome. Finally, we find that the relation between the magnitude of the shift and the size of stable coalitions may be negative.

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Introduction

Many natural systems can undergo sudden, dramatic changes in their dynamics in response to a change in environmental conditions or human activity. When such a system provides value through the provision of an ecosystem service such as shoreline protection by mangroves or the harvest of fish, such a change in productivity, known as a regime shift, can have substantial economic consequences. Large swings in the abundance and growth of Pacific sardines led to the cessation of fishing in the early 1950s and a formal moratorium in 1967 (Radovich, 1981). Similar dramatic shifts in productivity have impacted cod fisheries in various parts of the Atlantic Ocean. Importantly, those shifts may have been affected by the level of fishing to which the stocks were subjected. In the Atlantic Cod fishery in the North and Baltic seas, Lindegren et al. (2010) find that areas subject to trawl fishing bans were less likely to experience regime shift than areas subjected to full commercial-scale fishing. The influence of fishing on regime shifts could act directly through reduction in growth rates or indirectly by making a fish population more susceptible to otherwise exogenous environmental drivers of regime shift (Collie et al., 2004).

While a substantial body of research examines the economic consequences of uncertainty in fisheries (e.g. Clark and Kirkwood, 1986; Costello and Polasky, 2008; Sethi et al., 2005) and a number of ecologists have studied the mechanisms behind regime shifts (e.g. Folke et al., 2004), the economics literature examining how the potential for such regime shifts

* Corresponding author.
E-mail addresses: s-miller@umn.edu (S. Miller), nkuiyamb@ualberta.ca (B. Nkuiya).

http://dx.doi.org/10.1016/j.jeem.2016.05.001
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affects optimal management of a fishery focuses only on harvest decisions.[1] Early work by Reed (1988) highlights two competing effects of such a threat. First, the threat of collapse acts in a similar way to a higher discount rate, since expected future harvest is smaller, suggesting higher optimal harvest rates. However, if the threat of collapse increases as the stock is fished down, there may be a countervailing incentive to reduce exposure to the threat by harvesting less. More recent work by Polasky et al. (2011) and Ren and Polasky (2014) clarifies the role that different assumptions about the consequences of the regime shift have on optimal harvest policies. In an applied setting, Costello et al. (1998) examine the value of information pertaining to a potential shift in a coho salmon fishery caused by El Niño.

All of these studies examine how a single resource user should adjust management choices when faced with the threat of a regime shift. However, there is also some evidence suggesting that such threats may motivate cooperation among multiple resource users in fisheries. The rock lobster fishery in New Zealand offers one compelling example. That fishery has been managed under a property rights scheme since 1990, but despite management efforts, catches showed signs of decline by 2006. In response to declining catches, fishers worked with scientists to evaluate management alternatives and in 2007 each voluntarily surrendered a fraction of his or her individual quota in order to avoid collapse of the stock and a shift to an extremely low productivity regime (Breen et al., 2009). This example suggests that the threat of regime shift may alter not only harvest choices, but also the calculus of cooperation.

This paper examines how the threat of a regime shift alters the incentives for cooperation in a shared fishery. In particular, we study how the threat of a regime shift alters both harvest and coalition membership decisions, and ask how those effects vary with (i) whether the threat is exogenous (stock-independent) or endogenous (stock-dependent), and (ii) the type of shift (complete collapse or drop in productivity). We address these questions using a stochastic dynamic game of harvest in which fishers repeatedly choose whether to join a fishing coalition and how much of the resource to extract.

Our work complements several prior contributions, many of which extend the standard Fish Wars model (Levhari and Mirman, 1980). This paper most directly extends the analysis of Kwon (2006), who studied partial coalition formation in a deterministic setting. Our primary contribution is to unite that study of deterministic coalition formation with the literature examining the impacts of the threat of regime shift on harvest decisions of sole owners or sets of fully non-cooperative players. In particular, our work complements Fesselmeyer and Santugini (2013), who consider fully cooperative or non-cooperative players facing an exogenous threat of regime shift, but do not consider partial cooperation. Sakamoto (2014) extends the sole owner analysis to endogenous threats, but does not consider the formation of coalitions. Diekert (2015) examines a related problem with distinct dynamics, illustrating that the threat of collapse triggered by excess harvest can cause non-cooperative players to choose socially optimal harvest levels. He does not, however, consider coalition formation, shifts that alter productivity, or stock-dependent threats. Finally, Walker et al. (2015) address similar questions to those presented here, but focus on open-loop strategies and find that coalitions with more than two members are not stable when considering fully dynamic payoffs. In our model, players choose feedback strategies, reconsidering both harvest and membership decisions each period as is true in many real-world settings (e.g. Regional Fisheries Management Organizations, RFMOs).

Our analysis suggests that the threat of regime shift alters harvesters' responses as compared to the standard cases where either such a threat is absent, or players are assumed to act either fully cooperatively or non-cooperatively. Not only do we find that partial cooperation may arise, but we also find scope for heterogeneous responses to the threat of regime shift, which cannot arise if all players cooperate or all harvest independently. Further, we find greater scope for cooperation when players may update membership decisions than if players face regime shift but must commit to cooperation once and for all. Finally, while we find cases in which non-cooperative harvest is sufficient to limit exposure to the shift, in other cases only cooperation can reduce the probability of the shift.

We first examine the scenario where the abrupt occurrence of the shift reduces the resource growth rate but does not cause extinction. Analytical results indicate that when the probability of regime shift is exogenous and known, no more than two players cooperate. The threat may induce a stable coalition with two fishers that would not exist in the absence of the threat, but overall an exogenous threat of regime shift supports only small coalitions. In addition, we find conditions under which, prior to the shift, members of a stable coalition reduce their harvest whereas each non-member increases his harvest. When we instead consider the case where the probability of regime shift is endogenous (depends on harvest decisions), we find that larger stable coalitions are sustainable prior to the shift. In particular, we find in this context that the threat may induce full cooperation as an equilibrium outcome, though those coalitions may dissolve as the stock recovers. We repeat these analyses for a scenario in which the shift entails a doomsday event in which the stock collapses. We find that a harvester may undertake cautious behavior in response to the threat when the probability of regime shift is exogenous. In the case where the likelihood of the shift is endogenous, we show numerically that the grand coalition can be stable. We of course do not interpret these findings as implying that full cooperation will always arise in fisheries. However, our analysis does suggest the threat of regime shift may play an important role in determining the level of cooperation that does occur.

Our analysis also contributes to an interesting literature addressing in an infinite horizon framework the control of pollution under the prospect of exogenous and endogenous regime shifts. For instance, Clarke and Reed (1994), Tsur and

[1] A related literature examines the effects of regime shift in other contexts, such as forestry, ozone depletion, or greenhouse gas emissions. Examples include Cropper (1976) and Nkuiya et al. (2015).

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