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Management of a transboundary wildlife population: A self-enforcing cooperative agreement with renegotiation and variable transfer payments

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Abstract

This paper characterizes a dynamic contract that allows renegotiation and variable transfer payments (VTP) between owners of two independently-harvested, ecologically-dependent mammal populations. The decision environment is modeled as a two-person differential game. We develop a *recursive-efficiency* criterion that forms the basis for determining the size of the VTP, which makes the bargaining contract *renegotiation-proof* and self-enforcing. We further show that the VTP is just as Pareto-efficient as a lump sum or fixed annual transfer payment. A nuisance wildlife species management forms a basis for numerical illustration.
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Keywords: Migratory population; Differential games; Variable transfer payments; Renegotiation proofness; Bargaining agreements

1. Introduction

Past bioeconomic work has investigated how economic agents (e.g., countries or private landowners) might negotiate self-enforcing agreements to cooperatively manage shared stocks of transboundary resources [2,8,13,14,16,17,19–22]. For example, agents may undertake to collectively harvest, or control the damage inflicted by, shared resource stocks, and to split associated profits or costs per a pre-negotiated formula.[1] Such agreements increase economic efficiency by internalizing stock and diffusion externalities arising from noncooperative management. They can be made self-enforcing to varying extents by incorporating economic

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[1]Others have explored the possibility of 'collusion' among two or more owners of shared resources either through tacit or expressed policies such as a threat of trigger strategy and without transfer payments [13,17]. Kaitala [13] demonstrates that players may flip-flop between cooperative and non-cooperative (trigger strategy) modes because of the imperfect information about each other's harvesting behavior in the previous periods. When they can observe other's behavior, they have no incentive to breach the agreement. McKelvey [17], on the other hand, deals with a different type of collusion among a sub-group of aggressive competitors who may tacitly form a coalition to keep weaker competitors out of the game. As a result, the shared resource stock may be in a severely degraded state.

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incentives—typically a program of transfer payments among the agents—to discourage breach and a subsequent return to noncooperative behavior. Self-enforcing mechanisms are useful when 'binding' agreements are infeasible because no external body exists to impose sanctions upon those breaching the agreement [14].

Past bioeconomic work formulates transfer-payment mechanisms among contractual agents in the context of a differential game involving either a lump-sum payment [19,20], or an annual fixed transfer payment (FTP) [14,26]. An FTP is determined ex ante (before the game unfolds), and its size is normally tied to initial time, initial resource stocks and other model parameters. A problem arises when an FTP schedule fails to sustain cooperation as the game unfolds because contractual agents "later find themselves in situations where the agreement made during the pre-play negotiations is no longer as tractable as it seemed to be at the time the agreement was made" [14, p. 100]. An agent becomes better off by breaching the agreement, forgoing the FTP, and reverting to noncooperative behavior.

Kaitala and Pohjola [14] approached this problem by developing an FTP contract in which compliance by each party is monitored by the other as the game unfolds. The management context is two countries that jointly manage a shared single stock of a transboundary marine resource. The countries enter into an agreement that calls for the more-efficient country to buy out the less-efficient country from the fishery with an ex ante-determined FTP schedule. The more-efficient country then undertakes sole harvesting at its sole-owner optimum. Both countries monitor the progress of the contract at regular time intervals. If either country is found to have breached the agreement, both countries implement their respective *trigger* strategies, i.e., a non-cooperative Nash strategy without side payments, for the remainder of the game. Kaitala and Pohjola [14] derive limited conditions guaranteeing that the set of agreeable FTP's associated with the cooperative equilibrium stock level remains agreeable at every stock level reached during the agreement (Lemma 1, p. 105).

We extend this line of work by formulating a more flexible dynamic contractual mechanism that allows for resource users to make ex post adjustments in the schedule of side payments based on resource stocks observed at each stage of the game. In particular, both agents monitor the progress of the contract at the beginning of each stage, and, if either is dissatisfied, they renegotiate ex post the schedule of side payments as an alternative to each reverting to a noncooperative trigger strategy. Such an agreement results in a variable-transfer-payment (VTP) contract that is 'renegotiation-proof' in the sense of Rubinstein and Wolinsky [24]. That is, after the contract has been renegotiated at the beginning of a given stage, it cannot be further renegotiated to an agreement that is preferred by both agents until the next stage. The VTP contract protects resource users from receiving inefficient payoffs in perpetuity (unlike a lump-sum payment or an annual FTP agreement), and is demonstrated to be Pareto-superior to all other agreements.

The self-enforced dynamic contracts with transfer payments have also been addressed in the context of cross-border environmental pollution problem. Chander and Tulkens [3] applied the core-theoretic concept to a static game of multiple countries wherein a core group of countries stick to a cost-efficient transfer payment agreement, which is shown to be sufficient to deter a free riding temptation by countries belonging to another coalition. The same concept has been later applied to dynamic problem but as an ex ante negotiation or open-loop problem [6]. Germain et al. [7] in a more recent paper combined the core-theoretic concept with periodic renegotiation provision, resulting in a closed-loop, transfer payment program. The game formulation in our paper does not utilize the core-theoretic concept since we have only two players, but provides for renegotiation.

We investigate VTP contracts in a significantly different management context that requires a multi-dimensional bioeconomic specification. Adjacent landowners contract to cooperate in the control of two small-mammal nuisance-wildlife populations of the same species (one on each parcel) that are connected ecologically by an inter-parcel migration process.[2] Unilateral control efforts encourage free-riding behavior on the part of the other landowner [12]. Specifically, wildlife from the free-riding parcel may follow a

[2]An important real-world example of a potentially nuisance small-mammal population is the beaver. Beaver populations in many parts of the United States have increased alarmingly over the last 40 years in response to regulated trapping, and have caused tens of millions of dollars in forest and crop damages due to their timber-girdling and flooding activities [11]. In a specific case, beavers are damaging a wildlife habitat that the Circling Raven Golf Club (Worley, Idaho) is developing as part of Audubon International's Cooperative Sanctuary System. In building five dams along a small stretch of stream, beavers denuded a bank of cottonwoods [Spokane Spokesman-Review, Monday, May 17, 2004].

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