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Cooperative bargaining to manage invasive species in jurisdictions with public and private lands

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ABSTRACT

Mixed land ownership affects the scope for cooperative bargaining between jurisdictions to undertake control activities to slow the spread of an invasive species. We consider a problem in which emerald ash borer (EAB) spreads from an infested to an uninfested jurisdiction, where both contain ash trees on public and private land. We develop a dynamic model of cooperative Nash bargaining to examine how the mix of land ownership within each municipality affects the path of a negotiated transfer payment from the uninfested to the infested jurisdiction. Using a numerical simulation, we demonstrate that a bargaining agreement can be reached only below a threshold level of public land ownership in the infested municipality. The value of this threshold depends on the effectiveness of the transfer payment in supporting more intensive control efforts, such as tree removal, that delay spread. In a landscape with mixed ownership, free riding by private landowners on the public control effort is one factor that leads to a decrease in this threshold. We also find that in the presence of free riding, a bargaining agreement can only exist if the jurisdictions commit to a path of transfer payments that spans multiple years. This suggests a role for higher government to play in supporting multi-year cross-jurisdictional agreements.

Introduction

Forest bio-invasions cause significant economic losses as pests spread across property boundaries (Holmes et al. 2006; Kocavs et al., 2011; Sydnor et al. 2007). As invasive species spread across the landscape, the control choices made by one decision maker generate an externality by influencing the likelihood that the pest will spread onto other properties. This problem is well studied in the economic literature, typically as a problem in which control decisions are undertaken by neighboring property owners (Atallah et al. 2017; Büyüktahtakin et al. 2013; Epanchin-Niell and Wilen 2012, 2015; Fenichel et al. 2014; Kovacs et al. 2014; Liu and Sims 2016). Control decisions may be made at a range of scales, from private landowners to public entities, such as cities, states, regions, and countries (Wilen 2007).

A complication that is less well studied arises when the landscape contains a mix of publicly and privately owned land that houses the host species. Examples of mixed land ownership include the wildland–urban interface where private property meets undeveloped vegetation (e.g., national forest), and communities with ornamentals on public streets and parks that are interspersed among private property. Mixed land ownership oftentimes means that public land managers are unable to access and treat the host species on private land. In this setting, control decisions on private land can alter the effectiveness of treatment efforts on public land. This affects the incentives of public land managers to undertake costly control activities and, in turn, the spread of the pest over space and time. This is a problem similar to that modeled by Atallah et al. (2017), in which the externalities generated *within* a decision-making unit affect the spread of a pest *across* decision-making units.

In this study, we examine how mixed public-private land ownership within a jurisdiction affects the control incentives of public land managers to slow the spread of an invasive species. Specifically, we are interested in how mixed land ownership affects the incentives of jurisdictions to cooperatively bargain with one another to control the spread of an invasive species from an infested to an uninfested jurisdiction. A number of studies in the economic literature examine cooperative bargaining between actors as a mechanism to slow bio-invasions. Often, cooperative agreements take the form of a transfer payment that facilitates cost-sharing to support higher control efforts in infested areas (Bhat and Huffaker 2007; Kaitala and Pohjola 1988; Sumaila 1997). For example, Bhat and Huffaker (2007) discuss transfer payment schemes to control dispersion of mammal populations over

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time across landowner boundaries. These studies demonstrate that bargaining can play an important role in cooperative control and that transfer payments are important to self-enforcement of pest spread. However, we are not aware of a study that considers whether mixed land ownership might affect the likelihood of actors to engage in bargaining or the form that a bargaining agreement might take.

A current and prototypical example of a cross-boundary invasive species that reproduces in host species across mixed public and private land is the emerald ash borer (*Agrilus planipennis* Fairmaire), hereafter abbreviated EAB. EAB has already destroyed ash trees (*Fraxinus* spp.) throughout the U.S. (Anulewicz et al., 2008). The Twin Cities of Minneapolis and St. Paul, Minnesota have seen the rapid spread of EAB since the pest was initially detected in St. Paul in 2009. EAB quickly spread throughout the region and has now been detected in Olmsted, Winona, Houston, Hennepin, and Dakota counties (Minnesota Department of Agriculture 2014). To control EAB infestation, some municipalities (including St. Paul), have chosen to delay or avoid ash tree removal by using systemic insecticide treatments. Others (including Minneapolis), have chosen to remove ash trees from public lands. Unfortunately, public control of EAB on privately owned land is not possible, and thus it is not surprising that the total estimated costs of controls in the region to all landowners are estimated to range in the billions (Kovacs et al. 2010, 2011).

In our analysis, we propose a dynamic bio-economic model to study the potential for cooperative bargaining across municipalities to control EAB spread. Our approach is novel in that we allow for a mix of public and private land within municipalities, while also allowing a mechanism for cooperative bargaining across municipalities.[1] Cooperative bargaining involves a transfer payment from an uninfested to an infested municipality to encourage greater levels of control than the infested municipality would choose in isolation. By adopting higher-intensity control, the infested municipality's costs of control increase, but the probability that the pest will spread to the uninfested municipality decreases. Thus, both municipalities stand to gain from bargaining with one another to reach a cooperative agreement. We model the agreement outcome using an axiomatic Nash bargaining approach to demonstrate how the nature of a bargaining outcome depends on land ownership within each municipality.

The Nash method we choose for bargaining is less important here than the basic (and real) problem of differences in incentives to control across adjacent municipalities. Spread of EAB in our model occurs over time according to a biological equation of motion, and we consider the realistic possibility that private landowners may free ride on public control efforts supported by a bargaining agreement. We calibrate our model with data on the EAB infestation from the Twin Cities, where a mix of private and public land ownership affects the benefit and costs of public control efforts. We use this case to demonstrate the utility of our model, but the basic approach we propose is transferable to any situation where municipalities have the opportunity to cooperate to control the spread of an invasive species, but where local governments have limited or no access to private lands to implement control activities.

In our model, mixed land ownership influences the bargaining agreement via two effects. An increase in public lands means that higher-intensity control is undertaken on more land (a direct effect), but at the same time a dollar of transfer payments is spread over a larger land base (an indirect effect). The latter effect reduces the marginal efficacy of the transfer payment in slowing EAB spread. We find that these competing forces drive the bargaining solution away from the first-best outcome as public land ownership increases. However, we also find that the effect of public land ownership on the agreement is non-linear: there is a threshold in the proportion of public lands in the infested municipality above which bargaining is not feasible. Below the threshold, bargaining reduces social costs substantially, relative to the disagreement outcome. Above the threshold, the jurisdictions revert to the disagreement outcome and maximum social costs. We show that the value of this threshold is a function of any activity that reduces the efficacy of the transfer in slowing spread, including free riding by private landowners on the public control effort. As free riding increases, the threshold decreases, which reduces the viability of cooperative bargaining as a mechanism to control the invasion. Thus, land ownership is a critical concern in choosing how to manage forest invasive species in jurisdictions with mixed land ownership.

The remainder of this paper is organized as follows. Section 2 describes the modeling framework for a bilateral Nash cooperative bargaining problem between an uninfested and an infested municipality, where each contains a mix of public and private land ownership. Section 3 describes the data we use to numerically simulate the cooperative bargaining outcome. Section 4 presents results and sensitivity analyses for a range of values in the proportion of public land ownership as well as free riding by private landowners in the infested municipality. Section 5 presents conclusions.

Theoretical model of pest control

Suppose at time $t = 0$ there is a municipality infested by EAB, denoted by subscript I. The municipality is adjacent to an uninfested municipality denoted by subscript U. Let the constants $(0 \leq q_I \leq 1)$ and $(0 \leq q_U \leq 1)$ define the proportion of public land in each municipality (where $1-q_I$ and $1-q_U$ are the proportions of private land). In the absence of cooperation, the uninfested municipality faces a probability at time t, $0 \leq p(t) \leq 1$, that EAB will spread from the infested municipality.[2] Biological pest spread grows according to $\dot{p}(t) = f(p(t))$, where $\dot{p}(t) = dp(t)/dt$ is the rate of growth in the probability of spread and $f(p(t))$ is a biological growth function for which $f'(p(t)) > 0$.

Our focus in this analysis is on the problem facing these municipalities prior to spread of EAB from the infested to the uninfested location. In this context, the infested municipality will under-control EAB relative to the socially optimal level because it does not benefit from the external net benefits of control to the uninfested municipality. It is therefore reasonable to expect that the uninfested municipality has an incentive to provide assistance to the infested municipality. We consider this assistance in the form of a transfer payment, $\tau(t) \geq 0$, which is made from the uninfested municipality to the infested municipality at time t in return for higher-intensity control in the infested location. We model the control in the infested municipality as an index that increases in intensity with the size of the transfer payment. An increase in control intensity in the context of EAB usually involves the removal of ash trees, though the control index is sufficiently general that it may capture a change in the mix of control activities, such as increased monitoring or more aggressive treatments with insecticide.[3]

The transfer payment from the uninfested municipality is used to support the control of EAB on public lands in the infested municipality.

[1] Our work also differs from Berry et al. (2017), who consider switching frontiers explaining control of EAB where it may or may not be optimal to invest in these activities. Our focus is on cooperative bargaining and the importance of private and public land mix, for ranges of invasion possibilities that are relevant for cooperative mechanisms.

[2] In some cases, it may not be possible to reduce the probability of spread to zero, for example if a small population of the invasive species remains despite treatment efforts. We assume a lower bound of zero without a loss; the model is sufficiently flexible to incorporate an arbitrary, exogenous lower limit such that $p_{min} \leq p(t) \leq 1$.

[3] In this analysis, the mechanism available to the uninfested municipality to prevent infestation is to slow the spread of EAB from the infested municipality. We do not model the choice of *ex ante* control in the uninfested location, such as the preemptive removal of ash trees. However, we do take into account the fact that once the uninfested municipality becomes infested, it must then use costly control within its own boundaries, both to preserve the ash canopy and also to remove dead and dying ash trees that pose a public safety hazard.