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# Private eradication of mobile public bads[☆]

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ABSTRACT

We consider analytically the non-cooperative behavior of many private property owners who each controls the stock of a public bad, which can grow and spread across spatial areas. We characterize the conditions under which private property owners will control or eradicate, and determine how this decision depends on property-specific environmental features and on the behavior of other landowners. We show that high mobility or lower control by others result in lower private control. But when the marginal dynamic cost of the bad is sufficiently large, we find that global eradication may be privately optimal – in these cases, eradication arises in the non-cooperative game and is also socially optimal so there is, in effect, no externality.



## 1. Introduction

The management of public bad resources represents a ubiquitous challenge with real-world policy implications. Applications are numerous and include diverse resources such as infectious diseases, fire, invasive species, antibacterial resistance, noxious advertising, cyberspace viruses, and aquaculture pathogens, among many others. Controlling these nuisances is complicated by their mobility and renewability since they may grow and spread to surrounding areas in subsequent periods, thus imposing future damages in other locations. While the literature often focuses on socially-optimal management,[1] issues

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[1] Among others, Lichtenberg and Zilberman (1986) and Archer and Shogren (1996) seek to optimally control a pest population, other biological invasions (Olson and Roy, 2002; Shogren, 2000) or infectious diseases (Gersovitz and Hammer, 2004; Wiemer, 1987). Adda (2016) provides an evaluation of health-related policies relying on cost-benefit analysis.

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that arise when individual property owners each make decentralized decisions have received less attention for renewable public bads. Indeed, spatial connectivity induced by the mobility of these resource influences private decisions, which collectively can have important consequences for control or eradication across the spatial domain.[2]

Our objective is to provide a general, theoretical treatment of non-cooperation over renewable, mobile public bads. This has important parallels with the canonical transboundary pollution problem where spread of the bad is also a prominent feature. But because our focus is on renewable public bads, we must also account for resource growth. This class of bads, which includes applications such as insect pests on agricultural fields, infectious diseases in countries, and head lice in an elementary school classroom, differs from the transboundary pollution problem in one more fundamental way. For these public bads, eradication is a viable policy option; this type of corner solution has not been the focus of models of cross-jurisdictional emissions of, say carbon or sulfur dioxide, where global (or even local) eradication is not viewed as a policy-relevant option.

With these intended contributions in mind, we note that a growing, though disparate, literature contributes to the issue of public bad management from the spatial perspective. The literature on optimal control of infectious diseases commonly introduces a transmission parameter to capture the rate of spread, but typically does not model the spatial dimension of disease transmission (exceptions are noted in the review by Arino and den Driessche (2006)). An early literature on transboundary pollution, such as acid rain, sheds light on control of pollutants that are not only deposited in the emitting country, but transported by wind, or water, across borders. Calvo and Rubio (2012) provide an informative survey on dynamic models of international environmental agreements when pollution is transboundary, and Jorgensen et al. (2010) focus on dynamic pollution games. However, the transport issue is rarely considered. In van der Ploeg and de Zeeuw (1992) a quadratic welfare function is maximized, considering separate pollution levels in each country, and assuming that a proportion of the emissions spreads to other countries while the rest of the emissions remain at home. They contrast the open-loop Nash equilibrium and the Markov-perfect equilibrium. Mäler and de Zeeuw (1998) explicitly describe a matrix of transport coefficients of emissions and adopt specific functional forms (as do Kaitala and Pohjola (1988) and Escapa and Gutièrrez (1997)), to provide numerical simulations to discuss the gains from cooperation.

A distinction between pollution problems and the resource problems considered here is that the latter class allows for endogenous growth of a renewable public bad. For example, it has become common recently to examine the optimal management of an exotic species that is spatially distributed across the landscape. A sole owner accounts for all spatial connections and optimizes her control efforts across space to derive the optimal design of policies; provided that all externalities are accounted for, such a sole owner achieves the socially-optimal outcome. In this setting some authors focus on the question of prevention vs. control: Leung et al. (2002) find, for zebra mussels, that ex-ante prevention is more efficient than ex-post control, while Burnett et al. (2008) use the case of the brown tree snake in Hawaii, after having theoretically characterized the paths of expenditures and damages, to analyze the optimal integrated management of prevention and control. Others contrast long-run solutions from optimal control systems and solutions from a static optimization problem (Finnoff et al., 2010), or uniform vs spatially-optimized policy (Albers et al., 2010). Epanchin-Niell and Wilen (2012) numerically examine optimal policies over a range of spatial and ecological configurations, and stress the influence of these qualitative characteristics on policies. While some purely theoretical works exist (e.g. Blackwood et al. (2010)), most papers conduct numerical simulations either in stylized systems or in systems loosely parameterized by empirical observations because analysis tends to grow in complexity with the spatial domain. These focused numerical applications help establish insights in specific settings, but they also raise more general hypotheses that can be addressed by theory.

A second strand of literature explicitly introduces the non-cooperative nature of private property owners, and emphasizes mechanisms that can be used to induce cooperation. Grimsrud et al. (2008) show that coordination is more likely with low levels of invasion in a two-agent dynamic model. Epanchin-Neill and Wilen (2015) examine how different degrees of cooperation affect invasion and find that the degree of cooperation is related to control costs: less cooperation is required to achieve high control when costs are low relative to damages. Our analysis follows this line of research, but we rather provide a game-theoretical approach with many economic agents instead of conducting numerical analysis of a particular system. Our model also allows for heterogeneous landowners, for example with respect to costs, damages, and spread rates. We find that these sources of heterogeneity can significantly alter individual landowner incentives over control or eradication, suggesting that heterogeneity can play an important role in economic outcomes. Our theoretical approach allows us to home-in on the effects of different patterns of spread and infestation on non-cooperative outcomes.[3] This helps to generalize previous numerical results.

Modeling non-cooperation in a dynamic spatial context is a non-trivial task. As emphasized in the literature on the canonical transboundary pollution model, there are several non-cooperative solution concepts that may be used in dynamic settings. Open-loop Nash equilibrium (OLNE) and Markov-perfect (or feedback) Nash equilibrium (MPNE) are the most commonly used approaches. One critique of the OLNE concept is that it relies on unrealistic information sets and an infinite period of commitment (van der Ploeg and de Zeeuw, 1992). In many settings, it may be more realistic to allow agents to *a priori* condition the current management decisions on the state variable. Under that assumption, the appropriate

[2] Brito et al. (1991) and Geoffard and Philipson (1997) focus on the economics of vaccination (but not eradication) and abstract from issues raised by strategic interactions and heterogeneity.

[3] Barrett (2003) develops an insightful model of global disease eradication within a static and homogeneous setting.