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ANALYSIS

Biosecurity incentives, network effects, and entry of a rapidly spreading pest

*David A. Hennessy**

Department of Economics & Center for Agricultural and Rural Development, 578C Heady Hall, Iowa State University, Ames, IA 50011-1070, United States

ARTICLE INFO

Article history:
Received 12 December 2006
Received in revised form
24 November 2007
Accepted 26 February 2008
Available online 25 April 2008

Keywords:
Communication
Complementarity
Increasing returns
Infectious disease
Invasive species
Network economics
Public good

JEL classification:
D6; H4; Q2

ABSTRACT

Protection against pest invasion is a public good. Yet the nature of private incentives to avoid entry is poorly understood. This work shows that, due to increasing returns or network effects, private actions to avoid entry are strategic complements. This means that compulsory action, at least by a subset of parties, can be an effective policy. Both heterogeneity in biosecurity costs and the effect of private actions on the extent of the invasion threat are shown to have ambiguous effects on the magnitude of welfare loss due to strategic behavior. Communicated leadership by some party is preferred to simultaneous moves, and it may be best if the party with highest biosecurity costs assumes a leadership role.

1. Introduction

One of the many dimensions of globalization has been the unintended introduction of alien species into ecosystems. In some cases, the result has been drastic change in ecosystem equilibrium such that great harm has resulted. A host of economic issues arise when seeking to optimally control for these effects (Shogren and Tschirhart, 2005). The welfare and political aspects of Pigouvian taxes on transported goods, which can be hard to distinguish from trade tariffs, is one suite of issues that has received attention (McAusland and Costello, 2004; Margolis et al., 2002). Another suite of issues pertains to the allocation of resources between prevention and ex-post management, including whether to accept an equilibrium level of invasion or attempt eradication (Perrings, 2005; Olson and Roy, 2002, in press). As with the trade literature, in these models a central authority uses instruments to trade off welfare benefits against the sum of private and social costs without detailing any human behaviors that give rise to these externalities. Indeed, the existing body of economic work on prevention has largely had

* Tel.: +1 515 294 6171; fax: +1 515 94 336.
E-mail address: hennessy@iastate.edu.

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doi:10.1016/j.ecolecon.2008.02.023

an optimal control orientation whereby a central planner seeks to influence caretaking through a, possibly stochastic, control technology (Leung et al., 2005). Other research, in Batabyal and Beladi (2006), has taken an optimal queuing perspective to better understand socially optimal behavior at ports.

While these approaches are often well-justified when modeling government efforts to manage this class of problems, they assume a centralized approach that does not characterize the environment in which many important ecosystem protection decisions are made. In particular, these decisions are often made by unmonitored individuals who do not seek to maximize social welfare as they do not face the full consequences of their decisions. Thus, a game theory analysis is appropriate. The interest of the present work is in some behavioral features concerning the entry of a pest into an ecosystem. As we shall show, private decisions on entry endow the problem with apposite structure. For policy purposes, an important aspect of these unmonitored choices is the complementary effect they have on the marginal benefits others derive.

Consider the context of a lake where only a finite number of individuals have access to boating privileges. The lake is presently free of some rapidly spreading pest, be it a weed, microbe, mollusk, or small vertebrate. If the pest enters the lake it will colonize with certainty and reduce welfare to all users. Some action, perhaps boat inspection and cleaning prior to launch, eliminates the risk of entry. There are clearly externalities, as boat hygiene is a public good. All in the region benefit from the pest's absence without rivalry over the benefits, while non-acting firms cannot be excluded from the benefits.[1] But the action comes at a private cost.

Each boater's biosecurity decision depends upon her sense of what others are doing. If the sense is that few others clean then the threat of invasion in the near future is high and the expected marginal private benefit from action is low. If the belief is that most other boaters clean then this boater could be the weakest link and the incentive to clean is strong. There is a network effect somewhat similar to the classic problem of encouraging the first few pioneers to buy a telephone or a high-definition television (Shy, 2001). Explicit information that others clean should encourage this boater to do so too.

The problem may be viewed as one of transboundary pollution. The study of strategic interactions across boundaries has received attention in a variety of contexts, acid rain for example (Murdoch et al., 1997; Maler and De Zeeuw, 1998). Among the few papers that study in a formal way strategic issues concerning invasive species are Fernandez (2006) and Batabyal and Beladi (2007). Fernandez's context is one of invasive species stock accumulation at trading ports and trade-proportional species flows between these ports. Ports choose privately optimal control strategies that do not adequately account for trade spillovers. In such a game, the activity of one port in controlling a pest should be a strategic substitute for activities at other ports. Batabyal and Beladi study tariff policy to induce credible price signals on exporter biosecurity actions for imperfect substitutes produced in Bertrand duopoly by a home firm and a foreign firm.

In Section 2, the basic 'weakest link' public bad model is laid out. The view that pest invasion is a public bad that can arise at the weakest link has been proffered by Perrings et al. (2002). The weakest link technology has been used in modeling by Horan et al. (2002) and by Horan and Lupi (2005), but neither of these have studied the nature of inefficiency under strategic behavior. The model is then used to show that biosecurity decisions are strategic complements across players. This is of policy relevance because multiple Nash equilibria may be supported where the lower action levels are clearly Pareto inferior. Government regulation that compels a readily monitored subset of agents to act may induce others to act, and so may increase the welfare of all without the need for transfers.

Section 3 illustrates the model for the case of two players and heterogeneous costs. It is shown that more cost heterogeneity can increase or decrease the extent of welfare loss relative to first-best. This ambiguous effect on welfare loss also applies to the magnitude of a player's contribution to the risk of invasion. The role of leadership in this game of strategic complements (Milgrom and Roberts, 1990; Vives, 1990, 2005) is considered in Section 4. Leadership by some player increases welfare, but imposing it on the player least likely to biosecure may be Pareto preferred because that party's incentives are most likely to be enhanced. So as to draw out some of the model's constraints and how they can be modified, the framework is adapted to accommodate a nonfinite set of decision makers with a value enhancement motive for biosecuring. A brief discussion on policy issues and further work concludes.

2. Preventing entry

The basic technical model draws on joint production studies in Kremer (1993), Perrings et al. (2002), Horan et al. (2002), and Winter (2004). A region has N firms, labeled as $n \in \{1, 2, ..., N\} = \Omega_N$. Each firm seeks to protect potential value to the extent V_n, and each can take a biosecuring action. The cost of this

[1] A variant on this context is the introduction of an infectious disease into an island farming ecosystem by a farmer who goes abroad on a farm tour. Although not a significant human health concern, Foot and Mouth disease caused great economic loss when introduced into Taiwan in 1997 and the United Kingdom in 2001. Taiwan had to kill about 3.5 million hogs, and suffered revenue losses of about $1.5 billion per year for an indefinite period as it was locked out of export markets. The UK culled approximately 4.9 million sheep, 0.7 million cattle and 0.4 million pigs, with economic losses in the order of $4 billion (General Accounting Office, 2002). As far as we know, the origins of these outbreaks have never been established with certainty. According to Scudamore (2002), then the UK Chief Veterinary Officer, a Northumberland pig farm with a license to feed processed waste food may have been the initial farm. The farmer was later convicted of failure to inform the authorities of the disease, as it was on the list of notifiable diseases. He was also convicted of feeding untreated waste, as he had a responsibility to treat what he had a license to feed. This latter point identifies a biosecurity action at the border of the 'UK animal feed region.' Feed, animals, humans, vehicles, and wind can carry the disease. Public measures to prevent entry include a large variety of activities at country borders, as well as public awareness programs. In the end, there is heavy reliance on voluntary behavior on the part of international travelers, especially those involved in the agriculture and food sector.