



A game model of international trade, transport costs, invasive species, and protocol compliance [☆]



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ARTICLE INFO

Article history:

Keywords:

Compliance
International trade
Invasive species
Transport cost
Porter hypothesis

ABSTRACT

We study the duopolistic interaction between two monopolists located in two different countries who sell an imperfect substitute good in two markets. The traded good is transported between the two nations on ships using solid wood packing materials (SWPMs) and hence the presence of one or more invasive species is a problem. We use a game model to analyze this interaction in three steps. First, we study the benchmark case of autarky or no trade between the two nations. Second, we introduce transport costs and then study the effect of free trade on the profits of the two monopolists. Finally, we suppose that invasive species are present in the SWPMs. This fact requires compliance with an environmental protocol. We model this compliance by increasing the transport costs associated with trade and then demonstrate that a version of the so called Porter hypothesis holds. In other words, we show that compliance with a cost increasing environmental protocol can give rise to higher profits for the two monopolists under consideration.

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Introduction

Overview

The fact that invasive species¹ have been and continue to be introduced into one part of the world from another is now well known. Along with this recognition, new findings have emerged about the economic costs of such introductions, particularly the accidental ones. In this regard, consider the recent results obtained by Pimentel et al. (2005). Limiting their attention only to the United States (US), these researchers claim that the total costs stemming from the environmental damage and losses caused by invasive species are almost \$120 billion per year. In addition, there are approximately 50,000 non-native species in the US and this number is increasing over time.

Limiting attention to maritime international trade, the main subject of this paper, there are two key ways in which invasive species have been accidentally carried from one part of the world to another. First, many invasive species have been introduced into a country, often inadvertently, by ships discarding their ballast water. Cargo ships usually carry ballast water

[☆] We thank an anonymous reviewer and the Editor-in-Chief H. Oliver Gao for their helpful comments on a previous version of this paper. In addition, Batabyal acknowledges sabbatical funding from RIT and financial support from the Gosnell endowment, also at RIT. The usual disclaimer applies.

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¹ Invasive species are also known as alien or non-native species. In the remainder of this paper, we shall use these three terms interchangeably.

in order to increase vessel stability when they are not carrying full loads. When these ships come into a seaport, this ballast water must be jettisoned before cargo can be loaded. This manner of species introductions is important, and [Nunes and Van den Bergh \(2004\)](#), [Yang and Perakis \(2004\)](#), and [Batabyal and Beladi \(2006\)](#) have all studied the problem of managing alien species that have been introduced into a particular nation by means of the discharge of ballast water.

The second way in which alien species have been introduced into a particular country is by means of the solid wood packing materials (SWPMs) that are routinely used to secure international cargo on ships. These materials are frequently constructed from poor quality wood that is often from trees damaged or killed by pests. As a result, bark inclusions in the SWPMs increase the likelihood of one or more insects and it is now believed that alien insects such as the emerald ash borer, the Asian longhorn beetle, and the *Sirex noctilio* woodwasp were all accidentally introduced into the US via SWPMs. In addition, a joint report from the United States Department of Agriculture (USDA), the Animal and Plant Health Inspection Service (APHIS), and the United States Forest Service (USFS) has noted that nearly 51.8% of maritime shipments contain SWPMs and that infection rates for SWPMs are substantial ([USDA, APHIS, USFS, 2000, p. 25](#)). For example, inspections of wooden spools from China revealed infection rates between 22% and 24%, and inspections of braces for granite blocks imported into Canada were found to hold live insects 32% of the time ([USDA, APHIS, USFS, 2000, pp. 27–28](#)). Given the undeniable link between maritime trade and the transport of invasive species from nations where they are native to nations where they are not, economists have now begun to systematically analyze this maritime trade/invasive species introductions nexus. We now briefly review this literature.

Review of the literature

[Batabyal \(2006\)](#) constructs a queuing theoretic model of maritime trade and seaport inspections with one importing and two exporting nations. Using this model, he derives a ratio criterion that specifies a condition under which it makes sense for a seaport manager in the importing nation to grant favorable regulatory treatment to the imports from one or the other exporting nation. [Tu et al. \(2008\)](#) show that an escalation in the use of tariffs increases the likelihood of invasive species introductions by biasing trade flows toward increased trade in primary commodities and decreased trade in processed products.

[Merel and Carter \(2008\)](#) show that when a cleaning technology is available to foreign exporters and the optimal level of import inspections is both relatively inexpensive and strictly positive, a penalty levied on contaminated imports is likely to be a better policy than a simple tariff designed to reduce the overall volume of trade. [Batabyal and Beladi \(2009\)](#) use a trade model with four different market structures and identify conditions in which it makes sense to use tariffs to regulate invasive species and conditions in which it does not.

[Ameden et al. \(2009\)](#) study an agent based model of border enforcement for invasive species management. They contend that such a model can generate policy relevant findings about the behavior of an importing firm and the conditions in which an increase in enforcement can lead to a significant reduction in the risk from invasive species and the related crop damages. [Margolis and Shogren \(2012\)](#) use a political economy model of policy formation to demonstrate that it may be counterproductive to prefer policies that are designed to make imports contaminated with invasive species safer over policies that are explicitly designed to discourage imports.

[Lawley \(2013\)](#) estimates the parameters of a structural model and points out that a biosecurity import restriction such as US border inspections for foreign pests and diseases can also be effectively used to serve as a protectionist non-tariff barrier. Finally, [Springborn \(2014\)](#) constructs an adaptive management model that is designed to make decisions under environmental uncertainty. He shows that when risk aversion increases, the relative value of adaptive management goes up and hence this can increase the rate of what he calls “exploratory actions.”

The papers discussed above in this section have certainly advanced our understanding of many aspects of the nexuses between international trade and invasive species management. Even so, there is *very little* theoretical research on the ways in which the presence of invasive species and the required compliance with an environmental protocol influences the profits of exporting and importing firms.

Given this lacuna in the literature, we study the duopolistic interaction between two monopolists located in two different countries who sell an imperfect substitute good in two markets. The traded good is transported between the two nations on ships using SWPMs and therefore the presence of one or more invasive species is a problem. We use a static game model to analyze this interaction in three steps. First, we study the benchmark case of autarky or no trade between the two nations. Second, we introduce transport costs and then study the effect of free trade on the profits of the two monopolists. Finally, we suppose that invasive species are present in the SWPMs. This fact requires compliance with an environmental protocol. We model this compliance by increasing the transport costs associated with trade and then demonstrate that a version of the so called Porter hypothesis holds.² Put differently, we show that compliance with a cost increasing environmental protocol can give rise to *higher* profits for the two monopolists under consideration. To the best of our knowledge, this is the *first* theoretical

² As noted by [Jaffe and Palmer \(1997\)](#) and [Lanoie et al. \(2011\)](#), there are many versions of the so called Porter hypothesis which was initially stated in [Porter \(1991\)](#) and in [Porter and Van der Linde \(1995\)](#). One version holds that environmental regulations will stimulate environmental innovations. A second version maintains that properly designed environmental regulations need not reduce the profits of compliant firms. In other words, such regulations may actually make compliant firms efficient and hence more competitive. Clearly, if this last possibility arises then a compliant firm's profits will increase and this is the version of the Porter hypothesis that we work with in the present paper.

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