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Invasive Species, Border Enforcement, and Firm Behavior

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Globalization has led to a growing volume of goods moving among nations and the introduction of invasive organisms. Port inspection is a major form of protection against invasive species. We find that their effectiveness will increase through policies that reduce the cost and increase the effectiveness of pretreatment of products before they enter the ports.

Also in this issue

Globalization, and its accompanying increase in trade, has not been without complications. Agricultural producers in the United States claim that increases in imports under trade agreements such as the North American Free Trade Agreement (NAFTA) and the World Trade organization (WTO), have been the main cause of an increase in invasive species introductions. They argue that USDA's APHIS (Animal and Plant Health Inspection Service) and other responsible government agencies are not adequately addressing these risks. Industry groups have also pushed for more stringent policies concerning invasive species, arguing that the United States' reputation as an exporting country needs to be protected. In contrast, foreign agricultural producers and importers argue that U.S. producers overstate their vulnerability to pests with the aim of imposing more stringent sanitary and phytosanitary measures that effectively serve as protectionist barriers to trade. As trade volumes increase, these issues become more contentious.

The most obvious policy solution for addressing cross-border risk—increasing investment in border control measures to encourage international firms' risk-controlling behavior—is not as straightforward as it may seem. Funding is limited and border control efforts are highly complex, especially given institutional changes such as the transition of agricultural inspections from APHIS to the Department of Homeland Security, Customs and Border Protection in 2003. Increased border measures can cause indirect adverse effects, such as significant delays at the border and significant losses if products reach their final destination damaged or late. Increased border enforcement also causes unintended consequences by increasing firms' incentives for avoiding these measures.

Policymakers hope that border protection measures have a deterrence effect, that firms increase due care with respect to pest control. However, agricultural inspection officers indicate that avoidance and evasive behavior on the part of importers is a significant and complex problem. For example, importers of high-risk goods (e.g., prohibited goods or goods contaminated with pests) may attempt to circumvent enforcement efforts. Some may take overt action to avoid detection, such as falsifying cargo manifests, or placing contaminated goods in hard-to-reach locations or hidden compartments. A more subtle approach to avoid detection is "port shopping," the practice of directing shipments to ports where importers believe products will undergo less scrutiny based on the enforcement reputation of inspectors at different ports. Importers port shop in order to avoid inspectors who are considered especially effective or well informed concerning companies with poor reputations. Alternatively, firms may respond

Port inspections are essential to reducing or eliminating invasive species risk.

to increased enforcement with changes in import supply. That is, they may decrease the amount of goods they attempt to import, or import a different mix of goods. Even those importers who have no doubts about the quality of their goods, and have applied appropriate pest-control efforts, have incentives to avoid the inconvenience and delay associated with inspections.

Introductions of invasive species are low-probability, high-consequence events. Thus, collecting data on invasive species and trade, such as how many infected shipments pass through borders undetected or the probability of invasions resulting from these undetected shipments, is a challenge. Moreover, firm behavior, such as placing high-risk goods in hard-to-inspect locations or switching ports of entry, is difficult to quantify. This may explain in part the lack of quantitative research on border enforcement with regard to invasive species management.

To address this need, we undertook a multipart research project, funded through USDA's Program of Research on the Economics of Invasive Species (PREISM), that resulted in the development of an agent-based model of border enforcement. Agent-based modeling (ABM) or agent-based computational economics, a growing area of research, allows heterogeneous agents to interact, learn, and respond within a defined system, and can predict outcomes that arise from the selection of particular enforcement instruments. These techniques are only just beginning to be applied in agricultural and environmental economics research, and have never been applied to questions of importer and inspector behavior for border enforcement and invasive species management.

We first developed a theoretical model to analyze firm response to border enforcement and a spatially explicit damage function to estimate the impacts of invasive species introductions. We then constructed an ABM framework incorporating the spatially explicit damage function, and applied the framework to a representative commodity (broccoli), invasive species (crucifer flea beetle), ports of entry (Calexico and Otay Mesa, Mexico /U.S. land ports, respectively), and vulnerable location (California).

We used this framework to evaluate the impacts of port-specific and importer-specific enforcement regimes for a given agricultural commodity that presents invasive species risk. The ultimate objective was to improve the allocation of scarce enforcement resources and to provide an adaptable tool that can be used by policymakers to answer further questions concerning border enforcement and invasive species risk.

The theoretical model, which provided the underlying structure for the ABM, considered two enforcement regimes (destruction versus treatment of contaminated goods) and evaluated both intended and unintended firm response, as well as pest population effects. The results indicated that increased enforcement (in the form of higher inspection intensity) will not necessarily result in reduced pest risk. Importers may respond to increased inspection intensity by lowering shipment amounts and increasing point-of-origin treatment (i.e., care), but under certain conditions they may actually respond by decreasing care in order to lower the cost of shipment. Similarly, these same conditions also dictate whether or not firms will increase or decrease the level of care as pest populations increase at the point of shipment. In response to environmental conditions such as increased pest populations, firms may reduce output and increase due care, so a simultaneous increase in enforcement may not be necessary and, in fact, may be suboptimal. This is a critical consideration for policies that prioritize inspections on the basis of changes in the level of pests in specific exporting countries.

This model was extended to a two-port case. The results showed that a change in port-specific revenues or costs will make firms more likely to change their port choice. Less obvious were the results that a change in initial pest populations or a uniform change in enforcement may also bring about a shift in port choice. Of course, whether these changes are expected to be long- or short-term, the cost to firms to shift output between ports, along with firm type, will determine whether a change in port choice occurs.

We selected broccoli as the specific commodity pathway modeled in the project based on the data from the Work Accomplishment Data System collected by the USDA. The vast majority of the U.S. broccoli crops is grown in California—128,500 acres in 2006. The average value of these crops was approximately $4,700/acre. Broccoli exports in 2002 were valued at over $116.5 million, while imports were valued at $28.1 million, 89.4% of them from Mexico. In the upcoming years, trade volumes of broccoli may increase due to changes in broccoli tariffs under NAFTA.

The invasive species of concern for broccoli in our example is the crucifer flea beetle (*Phyllotreta cruciferae*) because of its potential as one of the most damaging pests for broccoli in California. Broccoli is shipped from Mexico to California via land ports (Calexico and Otay Mesa), airports (San Diego and Los Angeles), and marine ports (Long Beach). The analysis focused on shipments of broccoli from Mexico to California via two ports—Calexico and Otay Mesa, located in San Diego County. Calexico East handles both commercial and personal border crossings and averaged approximately 289,000 trucks per year between 2001 and 2006. Otay Mesa is the largest commercial crossing along the California/Mexico border and averaged approximately 724,000 trucks per year in the same time frame.

We developed a spatial damage function that estimated the probability of pest establishment, using a degree-day model to predict the occurrence and spread of the crucifer flea beetle in California, and the resulting damage to broccoli crops. Results from this analysis showed that the probability of emergence and spread of the crucifer flea beetle in California was higher from January through June, with the highest probabilities in January, February, and March. Examples of these probability maps are shown in Figures 1 and 2. The model assumes a constant level for the broccoli crop throughout the year. It should be noted that estimates for broccoli crop damage were based only on the influence of weather and climate as predictor variables.

The ABM was created and run in NetLogo, a free software package. A map of California broccoli crops was layered with the establishment probability maps, and additional spatial information on the location of ports of entry and major highways and transportation routes. Through the actions of the importers, the ABM allows the

Figure 1. Probability of Adult Flea Beetle Emergence: January 15–31

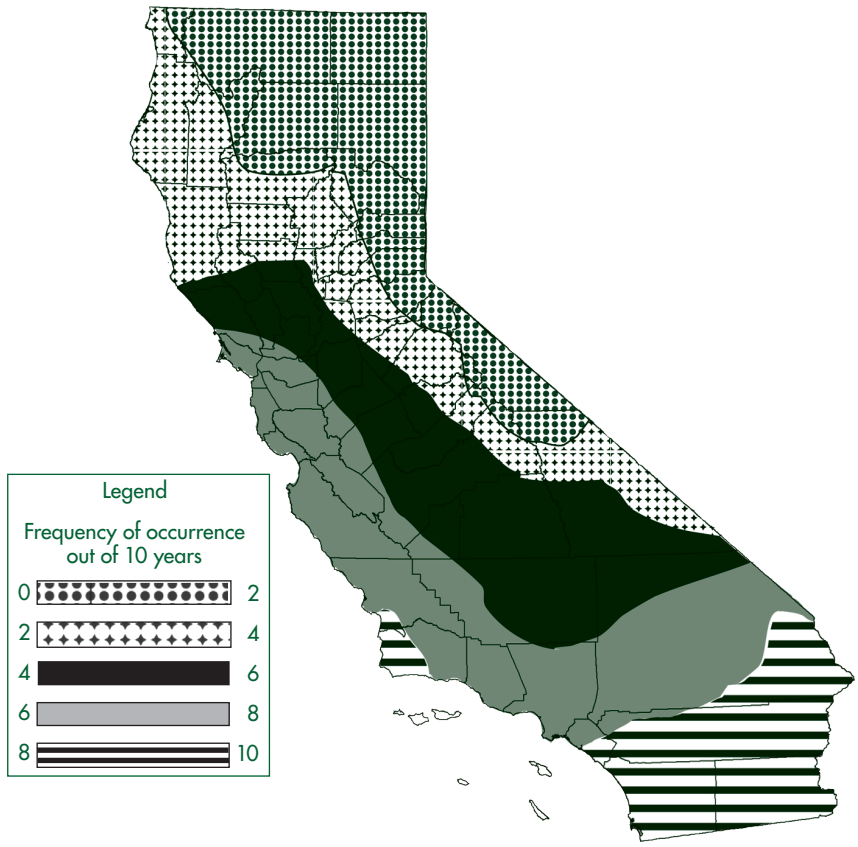
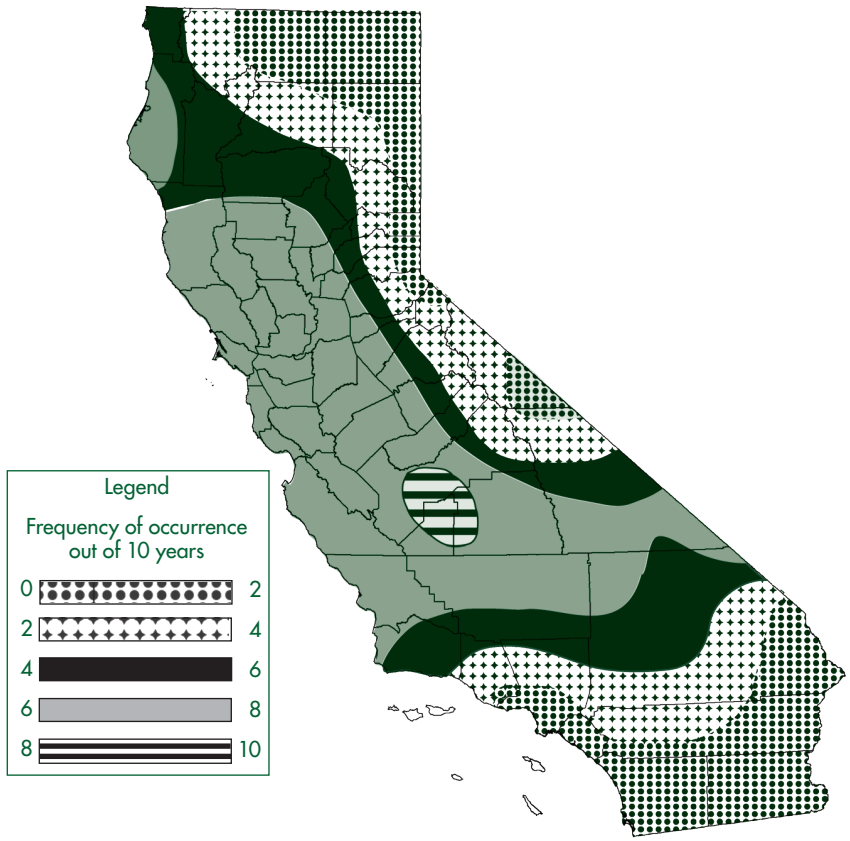


Figure 2. Probability of Adult Flea Beetle Emergence: February 15–28



crucifer flea beetles to be introduced and demonstrates the effects of border enforcement policies on broccoli crops. A key aspect of the ABM methodology is the capability to analyze the behavior of heterogeneous actors. In this model, three types of importers were created that differ in terms of infection rates (high, medium, and low) and cost of transportation to the port.

The model incorporates inspection rates for each port and each importer (to capture the effects of potential repeat offenders), and the success rate of inspection (i.e., finding an infected shipment when one is present), not only for each port and importer but also for each potential level of pretreatment.

The ABM analysis generated several policy-relevant findings. In addition to increasing pretreatment efforts in response to increased inspection rates, firms may switch away from one port to another with lower inspection rates.

While the model showed the expected reduction in crop damages as inspection rates were increased at a specific port, it also showed the conditions under which marginal damage reduction was flat versus steep. More dramatic damage reduction occurred when inspection rates at both ports were relatively high. The implications are that, under certain conditions, policymakers should not be focused on consistency across ports but rather on ensuring inspection rates at other ports are high. Alternatively, if inspection rates across ports are relatively low, unless inspection rates can be raised significantly and inexpensively at all ports, policymakers should not invest in increasing inspection rates at just one or a few ports.

This analysis highlights the policy importance of distinguishing between inspection rates versus the rates at which these inspections are successful. The results show that crop damages may increase as the base rate of inspection increases, given low inspection and inspection success rates for certain importers. Moreover, increasing enforcement efforts may not necessarily reduce invasive species risk.

Port inspections are essential to reducing or eliminating invasive species risk. Without inspections or the perceptions of inspections, importers lose the incentive to ensure that their shipments are pest-free. Importers will not invest money in pretreatment efforts if there are no potential benefits (such as saving money on violation fines). That said, given the model's findings that a dramatic decrease in damage follows a decrease in cost of pretreatment, regulators may more successfully reduce invasive species risk by targeting pretreatment costs and effectiveness rather than by expending more effort at the ports. While it is important to make sure that our trading partners are meeting our standards at the border, it may be even more important to help them find better—and cheaper—ways to do so.

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For further information, the authors recommend:

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