Reducing Non-native Species Introductions with Risk-based Inspection of International Trade

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Pests and pathogens can hitchhike on imported goods and cause substantial damage in new environments. Here we describe research that informs the design and evaluates the gains of a new U.S. program for inspecting imported goods to reduce pest introductions.

The importation of live plants, such as those planted in our yards or in pots in our homes, has long been a pathway for the unintentional introduction of non-native insect pests and pathogens to the United States. Notable examples of such introductions include the Citrus longhorned beetle (Anoplophora chinensis) and White pine blister rust (Cronartium ribicola), both of which have caused substantial damage by killing trees and have prompted costly control campaigns. The international trade vector has also been expanding at a substantial rate: over the past four decades, the dollar value of plants for planting imports to the U.S. has grown at 68% per decade.

The U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) is tasked with minimizing the entry and spread of pests, diseases, and weeds to protect agriculture and natural resources. As part of this mission, APHIS inspects shipments containing imported plant material at ports of entry across the country. However, resources for these inspections have not grown at the same rate as imports, prompting APHIS to reexamine the efficiency of shipment inspection policies.

Recently, APHIS has explored moving from a relatively uniform approach for inspecting shipments to a risk-based inspection approach that concentrates effort on sources of imports that have more problematic inspection histories. While the basic idea of risk-based inspections is simple, designing the actual system is complicated by the involvement of thousands of offshore producers, each likely to adapt their behavior to any change in the border inspection strategy. In a forthcoming study (Springborn et al., in press), we evaluate how to effectively design such a system: how should producers be categorized into high- versus lower-risk groups and how differently should these groups be treated (e.g., in intensity of inspections)?

Using a numerical model calibrated to the actual system, we find that adopting risk-based inspection can provide a greater incentive for producers to clean up their shipments, even for producers inspected with less intensity than under a uniform inspection approach. We estimate that shifting to a risk-based inspection approach can cut the expected rate of infested shipments entering the United States by one-fifth, simply by reallocating existing resources.

Overview of the Inspection Procedures

Inspection of live plant imports involves an inspector examining individual plants within a shipment for signs of pests or pest damage. Inspected shipments that are found to be infested—we refer to these as "intercepted" shipments—may be either treated, destroyed or returned, imposing a cost on the producer and preventing entry of the associated pests. Infested shipments may enter the United States if pests are not detected by inspection or a shipment is not inspected. When shipments are not intercepted, they continue on to their intended destination. Because the inspection process takes time, inspected shipments that are not intercepted still generate costs for producers due to delay and use valuable inspection resources.

Following the approach of APHIS, we differentiate shipments by their origin-commodity combination, where the origin is the country of export and commodity is the genus of plant.

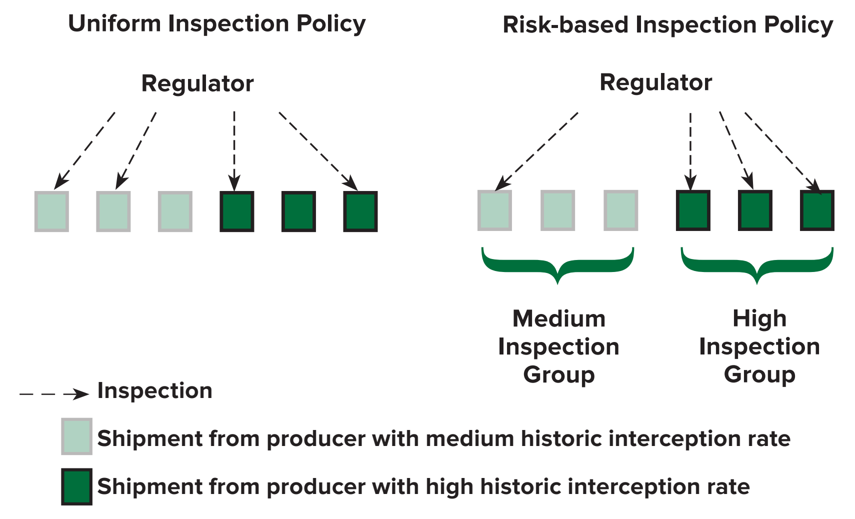

Figure 1. Under uniform inspection, all shipments face the same probability of inspection. Under risk-based inspection, higher risk shipments are inspected more frequently than lower risk shipments.

We refer to these unique origin-commodity combinations as "producers."

As illustrated in Figure 2, under a uniform approach, the regulator inspects all producers with equal likelihood. In contrast, under a risk-based inspection policy, producers are divided into medium- and high-risk groups based on their historic interception rates—a record characterizing previous inspection performance. Producers with a high historical interception rate are assigned to the high-risk group and receive more frequent inspections.

Historic interception rates are continuously updated to incorporate outcomes from recent inspections, capturing either deterioration or improvement in the cleanliness of a producer. As such, producers can move from the medium to high group and vice versa, based on performance.

Modeling Risk-based Inspection

In our risk-based inspection model, the regulator announces a cutoff that determines how producers will be treated—those with interception rates above the cutoff are placed in the high-risk group, with the remainder falling in the medium-risk group. The regulator also announces how inspection frequencies will differ between groups.

Producers respond by choosing their level of phytosanitary effort to reduce infestations in their shipments, with the goal of minimizing their expected losses. These potential losses come from the costs of phytosanitary effort, border inspection delays, costs from intercepted shipments, and being banned from the market entirely if interception rates are extreme. Phytosanitary effort is costly but reduces the anticipated level of all other losses.

In reality, it is typically not feasible for producers to control infestations with certainty. Nor is it possible for border inspections to intercept all infested shipments. Thus, we model uncertainty in both of these components. We empirically ground the analysis by using data on live plant imports and shipment inspection outcomes to estimate parameters in the model. We also calibrate our model of producer behavior so that the model replicates overall inspection outcomes observed in the data.

The ultimate goal of the inspection policy is to minimize the number of shipments that enter past U.S. borders but are infested. We identify the policy that minimizes the expected rate of these accepted infested shipments. The policy's focus on inspection highlights the role of border interceptions in preventing pest introductions. However, in reality—and in our model—reductions of accepted infested shipments come mainly from incentivizing producers to clean up shipments at the source, and only secondarily from interceptions at the border.

Benefits and Design of a Risk-based Inspection Policy

We compare outcomes under a risk-based inspection policy to those under a uniform inspection policy to evaluate the potential gains. Under a risk-based inspection policy, shipments from high-risk offshore producers are inspected more frequently and those from medium-risk producers are inspected less frequently.

Figure 2 illuminates the phytosanitary benefits of a risk-based inspection policy by comparing the predicted phytosanitary effort response (vertical axis) of a producer as a function of the producer's historic interception rate (horizontal axis) for both the baseline uniform inspection policy (dashed line) and the optimal risk-based inspection policy (solid line). Producers in both the medium and high-risk groups exert higher phytosanitary effort under a risk-based policy than under a uniform inspection approach

While producers falling into the medium-risk group—below the interception rate cutoff (thick vertical line)—are inspected less frequently under the risk-based policy relative to the uniform approach, they nonetheless exert higher phytosanitary effort than under the uniform policy. The reason for this is that they have a stronger incentive to provide cleaner shipments to avoid being transferred into the high-risk inspection group in which they would be inspected more frequently.

In addition, producers in the high-risk group, with interception rates close to the cutoff, exert substantially more phytosanitary effort than under the uniform inspection policy. These producers are motivated to increase phytosanitary effort to increase the chance of transitioning to the medium inspection group, where they would be inspected less frequently.

These two features of producer response under risk-based inspection, in which producers exert enhanced effort on either side of the interception rate cutoff, illustrate an idea known as "enforcement leverage." This enforcement leverage—combined with the direct effect of higher inspection frequency in the high group (relative to the uniform approach)—lead to reductions in the expected rate of infested shipment entering the United States.

Accounting for the behavioral response of producers (as above), the optimal risk-based inspection policy involves inspecting 100% of shipments from high-risk producers using approximately 82% of the available inspection budget.

Shipments in the medium-risk group are inspected with a probability equal to 0.28, almost one-quarter of the rate of high-risk shipments. The interception rate cutoff, determining group assignment, is set such that just over half (57%) of shipments entering the United States are assigned to the high inspection group.

We estimate that—relative to uniform inspection policy—the optimal risk-based inspection policy cuts the expected rate of infested shipments entering the U.S. by one-fifth. It does so by increasing inspection frequency in the high-risk group and decreasing inspection frequency in the medium-risk group—both by roughly 50%. This improvement is substantial, especially given that it results simply from reallocation of existing inspection effort.

To generate the results discussed above, we considered a model based on a single representative producer type. We considered a model that incorporated four different producer types as characterized by shipping frequency and phytosanitary effort costs. Incorporating this heterogeneity did not affect the results reported above, but did affect the level of the interception rate cutoff (vertical line in Figure 2), a policy parameter that must be announced by the regulator.

In reality, there is substantial heterogeneity, with thousands of producers that vary along a continuum. Fully capturing this heterogeneity is not computationally feasible. However, this is a design parameter that the regulator can settle on through trial and error, starting with high values—fewer producers in the high category translating to little risk that inspection resources will be overwhelmed—and iterating towards lower cutoff values until inspection resources are fully utilized.

Discussion

Given the substantial ecological and economic damages that can result from unintentional introduction of invasive pests via trade, measures to safeguard our natural resources are critically important. However, resources for implementing such measures are limited. Our research shows how shifting from a uniform policy to a risk-based policy for inspecting imported shipments of live plants can reduce the number of infested shipments accepted into the United States, and hence the likelihood of pest introduction, simply by reallocating existing inspection resources.

Our modeling results also help support effective design of a risk-based inspection program in the complex setting of international trade inspections, involving many more targets for inspection than considered by previous studies. We estimate that this approach would substantially enhance the performance of monitoring and enforcement efforts, even though the overall level of effort does not change, by targeting riskier shipments more intensively and incentivizing producers to clean up their shipments.

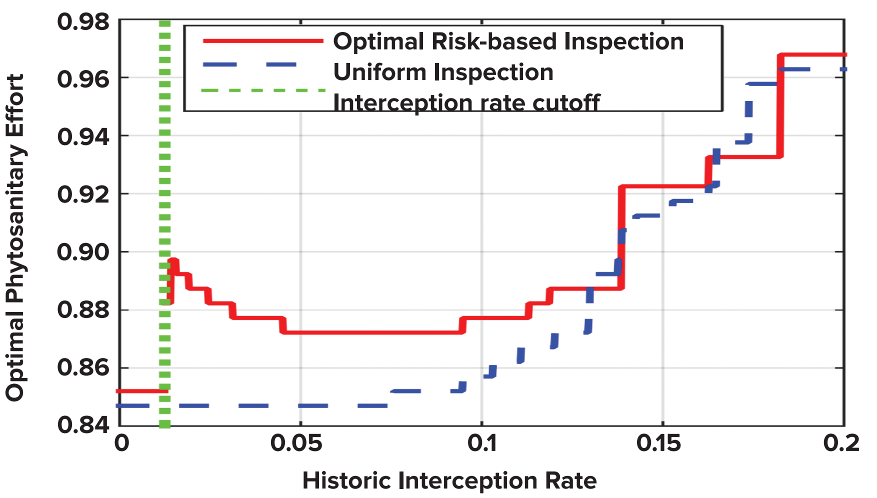

Figure 2. Optimal phytosanitary response for a representative producer (homogenous producer model). Phytosanitary effort is normalized to take a value between zero and one. When a producer's historic interception rate moves above 0.20, their shipments are banned from entry.

AUTHOR'S BIO

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For additional information, the authors recommend:

Springborn, M.R., A.R. Lindsay, and R.S. Epanchin-Niell. "Harnessing Enforcement Leverage at the Border to Minimize Biological Risk From International Live Species Trade." Journal of Economic Behavior & Organization. www.sciencedirect.com/science/article/pii/S0167268116300245.

MacLachlan, M., M.R. Springborn and A. Liebhold (2016). "The Hitchhiker's Guide to the Greenery: Estimating Dynamics of 150 Years of Trade-driven Non-native Species Introductions Via Plant Material." UC Davis working paper.