INVASIVE SPECIES IN AGRICULTURE: A RISING CONCERN

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"The Boll Weevil say to the Farmer,
You can ride in that Ford machine,
But when I get through with your cotton
you can't buy gasoline,
You won't have no home, won't have no home."

Boll Weevil Song (performed by Carl Sandberg in the 1920s)[1]

Invasive species are not new phenomena in U.S. agriculture, as illustrated by these 1920s lyrics from the Boll Weevil folksong. The boll weevil entered the United States via Mexico in the 1890s, and by the 1920s, this pest had spread to all cotton producing states, wiping out tens of thousands of acres of cotton, costing billions of dollars, and literally driving thousands of farmers off the land. There are similar examples in other parts of the world. In the 1860s, an agronomist transferred grape vines from the U.S. to France, to try to improve wine quality, and accidentally introduced phylloxera, a small louse that feeds on the roots of grape vines. As a result, France lost almost 75% of its vines at the time.[2] Despite this history of dealing with invasive species in the United States and elsewhere, many informational gaps remain with regard to optimal policies.

The purpose of this article is to provide the reader an introduction to issues concerning invasive species in U.S. agriculture. We explain why invasive species are viewed as a growing concern in the United States, and consider the role of economics. There are two aspects to that role. First, economic factors may influence the introduction, spread, response to, and control of invasive species, and ultimately determine whether an invasion is successful. We also argue that economists have a crucial role to play in terms of analyzing the problem and improving the understanding of the economic impacts of invasive species. Economists can evaluate alternative policy responses to deal with the uncertainty associated with any one of a vast number of potential invaders of specific ecosystems, and the resulting ecological and economic damage. While understanding interactions between species can be done in a purely biological model of an ecosystem, it is economic behavior—beginning with the mode by which the species was introduced, and certainly including patterns of production, marketing, and consumption—that determines how an invasive species affects agricultural industries and, ultimately, policy responses to invasions. We outline the various approaches that economists are taking in their research on invasive species, to incorporate these factors in modeling invasive species in U.S. agriculture.

In 2003, the USDA's Economic Research Service (ERS) instituted a three year competitive grants program aimed at improving the understanding of the economics of invasive species. The ERS program underscores the fact that policy makers realize there are important informational gaps when it comes to dealing with invasive species. Recently, there has been a flurry of legislative action directed at invasive species, at both the state and national level. For instance, in 2004 the California legislature passed a bill (AB2631) that establishes an Invasive Species Council to develop a statewide invasive

[1] http://www.simplelife.com/organiccotton/08WEEVLsng.html
[2] http://wine.about.com/library/weekly/aa052900.htm

species plan for the prevention, detection, and control of invasive species. Oregon and Idaho created similar councils in 2001 and 2003, respectively. A National Invasive Species Council was established by the President in 2003 (see www.invasivespecies.gov). It will be interesting, from a political economy perspective, to observe how these councils evolve—will they be relatively more focused on protecting agriculture or the environment, for instance, when conflicts arise? In addition, a number of Congressional acts have been recently passed, such as the "Brown Tree Snake Control and Eradication Act of 2003" (H.R.3479) to provide for the control of the brown tree snake on Guam and other areas such as Hawaii. Clearly, governments are prepared to develop new policies to respond to invasive species.

In agriculture, *invasive species* is a very broad term that typically applies to any non-indigenous pests, weeds, plants, insects, fungi, bacteria, viruses, and other disease-causing agents that can interrupt the production of livestock, crops, ornamentals, and rangeland. The term applies to pests that have entered the U.S., have moved to new locations within the U.S., or have the potential to enter the U.S. Damaging invasive species are not just an agricultural problem–they also affect industry, human health, and ecosystems. But not all invasive species are harmful, and some have been deliberately introduced for economic gain. For instance, the vast majority of crops grown by U.S. farmers today (e.g., rice, corn, wheat, and soybeans) are not indigenous to the U.S., yet they define U.S. agriculture and they have had a large positive economic impact on the nation (U.S. Congress). In this article we focus on issues related to harmful invasive species, most of which have been accidentally introduced into the United States.

There is renewed interest in invasive species today for two key reasons. First, scientists believe that both the speed and the extent of dispersion of invasive species have increased in the last few decades because of population growth, alteration of the environment, and globalization (Pimentel et al.). Globalization has led to growing trade volume and international trade is a common pathway for invasive species. Second, in the post 9/11 world, political fears include the possibility of the deliberate introduction of pests by terrorists–a biosecurity risk.

Economic analysis has an important role to play in the study of invasive species because the spread of invasive species is partly determined by human behavior. Economic incentives may influence the extent to which a particular invader can establish itself in an ecosystem. Furthermore, economists can estimate the cost of an invasion and the costs of managing an invasion, or even eradicating the species. Finally, economists can evaluate the effects of various control measures, and identify the optimal policy response. At the present time, policy response to invasive species is often conducted in an emergency situation, and it may be based on limited scientific data. The British management of the mad cow disease is a classic example of how not to handle a situation requiring an immediate policy response and when there is limited scientific data available. The government first indicated that humans were not at risk. Since then at least 200 UK residents have died from eating from eating BSE infected beef. Almost inevitably, emergency responses will ignore adaptations by firms and consumers, and hence miss the role played by human behavior. Ongoing research by economists will hopefully fill that void and introduce the economic dimension into models of invasive species.

Some invasive species have been intentionally introduced to an ecosystem, with their potential negative effects misjudged or not even estimated. For example, deer were brought to New Zealand from England and Scotland for sport in the 19th century. But they have become a serious pest in New Zealand, negatively impacting native species (especially grasses) and thereby reducing biodiversity in that country.

The possibility of unintended harmful consequences of an introduced species has become a key issue with regard to genetically modified organisms (GMOs). For example, some environmental groups (such as Greenpeace) and others are concerned that genetically modified (GM) corn from the United States imported into Mexico for animal feed was then illegally planted by some Mexican farmers. The belief is

that the bT corn will pollinate with native wild corn varieties and, through uncontrolled gene transfer, will eliminate native varieties that do not grow anywhere else, reducing biodiversity.
In the United States, pest resistance to bT corn is an issue. Pests that are not killed by eating GM corn could multiply, leading to a resistant pest population. This is the reason the U.S. government requires refuge areas around fields of GM corn. About 40% of the U.S. corn acreage is now planted to GM corn, and environmental activists are concerned that this “invasive” species may not only lead to uncontrollable pests but the corn itself with competitively overrun existing species due to economics.

Alternatively, some scientists believe that the introduction of GMOs will increase biodiversity through gene transfer, and that this could be beneficial. At the same time, the introduction of GM corn has a positive impact on the environment through reduced pesticide usage. The introduction of GMOs is a question of uncertain benefits and costs, and this is becoming a significant issue for western U.S. agriculture. For example, California has a big stake in GM crops but environmental groups and organic farmers are actively campaigning against GMOs in California, by highlighting potential economic and ecological risks of GM crops. The state of California has passed legislation that discourages the introduction of GM rice and some counties in the state have banned GMOs outright. Policy concerning GMOs and policy concerning invasive species thus share many similarities, and the economic analyses required for both are very similar.

How are economists researching the issues

Economists are conducting research that addresses many of the above mentioned issues regarding invasive species. Broadly speaking, there are three categories of ongoing research regarding invasive species: research addressing immediate policy needs, research developing new decision tools for policymakers and private actors, and research regarding aspects of the invasive species problem intended to contribute to future policy design and implementation. Of course, many economists may undertake research that spans multiple areas. For example, a project may develop a new decision tool and, at the same time, apply it to a current policy problem.

The first category of research focuses directly on providing input into the policymaking process using existing analytical approaches, or on improving the use of existing methods, such as Glauber and Narrod, who integrated the risk assessment and economic impact analyses used by the USDA to evaluate the impact of regulations intended to restrict the spread of karnal bunt, a wheat disease that originated in Southeast Asia. This type of research is valuable not only for its immediate contribution to policy, but also because it identifies the strengths and weaknesses of current approaches. Another research area in this category seeks to quantify the costs of specific eradication control procedures for specific invasive species problems. The book edited by Sumner includes a number of such case studies. While work in this area is almost by definition focused upon a specific problem, findings from specific cases can be used to aid in developing decision tools. For example, Knowler and Barbier model how to measure the costs of an invasion when it permanently changes growth rates for competing native species, and then apply this model to a comb jelly invasion of the Black Sea anchovy fishery.

The second category of research builds upon the first. Much of the work in this area focuses on bio-economic modeling and seeks to address the following research question: How can economists best use the often limited information available regarding the biological and economic parameters of an invasive species problem to provide input into the policymaking process? At least two levels of the policymaking process are included in this research question. First, policymakers must choose how to respond to a specific invasive species problem. Second, policymakers must choose how to allocate finite resources across invasive species problems. Recent work in this area includes a paper by Marsh, Huffaker and Long who develop a dynamic pest management model and use it to determine the optimal way to control a virus in the Northwest potato industry. The foundations for modern bioeconomic invasive-species models include work by Hueth and Regev, and Taylor and Headley.

Choosing the optimal response to a specific invasive species problem is generally modeled as an optimal control problem, due to the importance of population dynamics and how these dynamics interact with human decisions. Eiswerth and Johnson develop an optimal control model of a biological invasion, and solve for the optimal management decision. They emphasize the importance of the spatial dimension of invasive species control decisions, focusing on site characteristics, which affect the success of the invasion and control decisions. Among others, Brown, Lynch, and Zilberman address the importance of the spatial component of biological invasions and management decisions. The spatial aspect of biological invasions represents a new area where information is needed, and where economists must work with experts from other disciplines. For instance, our work on the greenhouse whitefly in California strawberries emphasizes the movement of the whitefly from crop to crop during the year, as its preferred host changes. Models of economic decisions made by producers concerning land use and crop selection thus interact with models from entomology concerning the growth and movement of the whitefly, to provide the framework for determining policy responses such as the registration of new chemicals to control the whitefly invasion.

This second research category addresses broader methodological questions of interest to economists. First, some work in this area integrates geographic information systems analysis with other economic considerations. Because there is an important spatial component to invasive species problems, this is a very promising research area. Second, risk and uncertainty are very important considerations when making decisions regarding invasive species. The potential economic and ecological effects of a given invasion could include a very large number of possibilities, and little or nothing may be known about the likelihood of each. Approaches to incorporating risk and uncertainty in invasive species decision models could be used for many other economic problems.

The third category of research examines different characteristics of the invasive species problem and policy choices. This research is primarily theoretical. Broadly speaking, the contribution of work in this area is to identify factors that may influence management and control decisions, but were not yet incorporated in current research in the two preceding research categories at that time. Hof developed a spatial-temporal model of managing an invasion that incorporates costly, location-time-specific management effort, and limited management resources. This model provides a template for developing decision tools for invasive species control. An early analysis of resident pest problem by Bhat, Huffaker, and Lenhart analyzed the value of a public agency as a means of implementing welfare-maximizing control measures. Their model of controlling the beaver population provides insights into the public role of invasive species control. The Boll Weevil Eradication Program in the American South, an area-wide program, provided an impetus for other early work addressing the value of collective action, although this work was primarily empirical, rather than theoretical. In order for the eradication program to be implemented in a given area, it had to be approved by a majority vote of cotton producers. Once approved, program participation was mandatory. This model may be of use when responding to other invasions, for instance, in helping to identify the workings of successful pest control districts.

Future Research

Policy makers have identified three key areas for invasive species research:

1. Comprehensive benefit/cost analysis of invasive species;
2. Evaluation of alternative control or management strategies; and
3. Combining biological and economic modeling.

Uncertainty in predicting the risks from invasive species and their economic impacts is a pervasive issue underlying all three areas. This is particularly true as it applies to biosecurity risks, but also for accidental introductions of new species or for pests that simply moved from one crop to another, as in the case of the greenhouse whitefly invasion of strawberry fields in California. In all three areas, the stochastic elements of the problem involve both biological and economic components. For instance, the movement of the greenhouse whitefly from crop to crop or field to field is not yet fully understood by entomologists, but they have identified the recent phenomenon of the summertime planting of a growing share of California strawberries as a contribution from producers to the whitefly's success. Newly planted strawberries provide a desirable host for the whitefly at a time of year when there previously had been less ideal hosts. The greenhouse whitefly problem in the California strawberry industry illustrates that there may be unintended, unpredictable consequences from invasions that occur when changes in human behavior interact with pest behavior that had not previously been observed. Among the most interesting features of invasive species modeling, therefore, is that neither economic models alone nor biological ones would capture these surprise outcomes.

The spatial and temporal nature of biological invasions, and uncertainty regarding effective control measures and the value of damages resulting from the invasion all suggest that collective action, whether publicly or privately coordinated, is an important consideration when making management decisions regarding invasive species, and one deserving of future analysis. Collective action may involve government policies alone, or involve pest control districts (either voluntary or mandatory). Industry groups may also take the lead. In any case, it seems likely that invasive species responses will not be limited to individual producers pursuing their own pest control strategy. Economists therefore can play a fundamental role in shaping the nature and extent of invasive species control policies. The PREISM program undertaken by the USDA's Economic Research Service, in collaboration with other researchers, includes research projects to make progress in all three categories. One theme of this research is the role of property rights, and differences in private and social benefits of invasive species management decisions. Another theme of this research regards the role of trade, and international aspects of invasive species control. (For more detail on specific projects, please consult the ERS website:
http://www.ers.usda.gov/Briefing/InvasiveSpecies/preism.htm).

Adapting previous information concerning the control of established pests is likely to fall short of capturing the population dynamics of new species, so interactions by economists in this effort with experts from the biological sciences are essential. The data requirements for both spatial and temporal aspects of invasive species behavior will be great, and will ultimately push modeling efforts in both sciences in exciting new directions.

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