Migration of Exotic Pests: Phytosanitary Regulations and Cooperative Policies to Protect U.S. Ecosystems and Agricultural Interests

by

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Introduction

In Executive Order 13112, President Clinton emphasized the need to prevent the introduction and to minimize the impact of invasive species to the U.S. ecosystems and agricultural industry. Exotic plants and insects can dramatically alter an ecosystem's balance and result in increased pesticide use which may negatively impact beneficial insects, water quality and human health. GAO (1997) estimates that the lost production, and prevention and control expenses from introduced plant pests is $41 billion annually. The Office of Technology Assessment (OTA 1993) reports that the potential cumulative economic loss caused by just 6 non-indigenous insects is $74 billion.[1] The establishment of the Mediterranean Fruit Fly *(Ceratitis capitata)* in the United States is estimated to cost $1.5 billion annually (Nichols, 2001). If the Mexican Fruit Fly (*Anastrepha ludens)* becomes established, the estimated 5-year loss would be $1.44 billion (Grimes, 1992). Historically, the projected losses from the establishment of exotic species have resulted in import bans or quarantine measures on all commodities from countries known to harbor the exotic insect.

Bans and quarantine measures enacted to protect plants from other plants (weeds), insects, and other pathogens are called phytosanitary regulations. Because tariff levels in the world have decreased since the first agreement of the General Agreement of Tarriffs and Trade (GATT), these phytosanitary regulations (also called non-tariff or technical trade barriers) are more likely to be binding. In addition, as countries attempt to protect domestic producers competing with foreign counterparts without tariffs, domestic governments may use these types of trade barriers when little scientific basis for these regulations exists.

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[1] Insects include the African honey bee, Asian gypsy moth, Boll weevil, Mediterranean Fruit Fly, Nun moth, and Spruce bark beetle. For comparison purposes, the expected losses from the establishment of foot and mouth disease was estimated to be $25.6 billion.

Roberts (1998) suggests that technical trade barriers can be used as a non-transparent means of providing protection for domestic producers from foreign competitors.

Domestic farmers support using import bans, arguing that the presence of exotic pests in production regions increases their costs, results in additional chemical applications, and may limit the movement of their agricultural products into export markets (including domestic markets in other states, such as Texas selling to California markets). Consumers may find that the exotic pests' damage results in higher prices for agricultural products and additional pesticide use, which may have environmental and human health impacts. Ecologists suggest that "when the outrageous economic and ecological costs of the wanton spread of existing exotics and continued entry of new ones becomes common knowledge, there will be a public outcry to mitigate the potentially dire consequences" (Niemela & Mattson, 1996). Exotic pests can be seen as a "public bad" like other forms of pollution. A standard economic conclusion is that under-abatement of this "public bad" will occur under perfect competition because individual producers and infested countries do not have to bear the full social cost of the pests' proliferation. Government intervention may be justified if regulators conclude that market mechanisms alone will fail to prevent or correct the negative externality since the resulting pest population in the domestic country may actually reduce domestic output and/or increase production costs (Roberts, 1999).

Even with import bans and quarantine regulations to inhibit direct migration on host commodities, exotic pests can act like trans-boundary pollution and not respect the border. Pests migrate through both natural and artificial pathways. They move great distances with wind currents and in water and soil. Basic artificial pathways are direct migration on the host commodity as well as on other items in aircraft, buses, ships, trains, trucks and automobiles. The proliferation of international trade and travel has increased exotic pests' opportunities to migrate into new countries. The industrial development and population growth along the U.S. and Mexico border is hypothesized to have resulted in increased numbers of the Mexican fruit fly in California and Texas. Smuggling of agricultural products has increased and may present an important pathway for exotic pests to enter the U.S. (GAO, 1997).

This paper examines theoretically and graphically whether the U.S. should use an import ban to decrease the threat of exotic pest migration from Mexico or work with Mexico to decrease the pest population and thus the probability of pest migration. In the strategic trade literature, if a government acts first and uses a continuous instrument,[2] it can improve the country's welfare (Brander and Spencer, 1985) in an imperfect market setting. This paper uses a competitive market model where the continuous instrument (tax, tariff, subsidy) is the level of pest control where the domestic government (U.S.) decides its own level and whether to subsidize the foreign country's (Mexico) pest control. The U.S. can also use a discrete instrument[3] (import ban) to affect domestic welfare. U.S. producers may benefit from the imposition of bans or quarantine provisions that exclude potential competitors and raise domestic prices. However, if Mexican growers cannot ship to the U.S. market, they may have less incentive to control the pest population; as the pest population increases, so does the likelihood of pest migration. As the U.S. price increases, the incentive to smuggle the commodities over the border also increases. If the exotic pests do migrate, the producer welfare decreases as pest control costs increase and other countries place bans

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[2]A continuous instrument could be a tax or a subsidy that would vary with the quantity or quality of imports.

[3]A discrete instrument could be an import ban. Regulators enact this type of policy or they do not, but it is not affected by the level of imports or the quantity of pests as a continuous instrument would be.

on the domestic commodities. The Mexican Fruit Fly (MFF) and Mediterranean Fruit Fly (Medfly) will be used as examples.

The following section includes the model development and discussion of comparative static results. A graphical analysis follows. A description of the current exotic pest protocol and cooperative techniques precedes the conclusions.

Theoretical Model

In the model, governments have perfect information about the underlying market structure and probability of pest migration. The domestic government has two continuous instruments: level of domestic pest control and level of subsidization of foreign pest control, and one discrete instrument: an import ban. The foreign government has one instrument: foreign pest control. Pest migration is assumed to occur only from the foreign to the domestic country, so no retaliation is included.[4] The model examines the provision of pest control (pollution abatement) and trade regulation selection in an open economy. The convention of the domestic country's variable appearing in lowercase letters and the foreign country's variables in uppercase letters is followed.

The model is a two-stage subgame perfect Nash equilibrium with each government committing itself to a level of pest control and/or a domestically imposed import ban. Once each government has determined the desired level of pest control and the domestic government has chosen whether or not to impose an import ban, the producers decide how much to produce of the homogenous product. Consumers choose their consumption level. The domestic growers sell to the domestic market and the

[4]Realistically, the foreign government could retaliate by using a ban on another commodity the domestic country exports to them.

foreign firms sell in both the domestic and the foreign market. Welfare of each country is a function of the levels of pest control and of the subsidy and whether an import ban is imposed. The reaction functions are determined by the game between the governments. The model is a static partial equilibrium two-country trade model with competitive market conditions. The market equilibrium quantities and prices are found and used to solve the game.

Competitive Market Model

Total cost function for the domestic industry is $c(q, n)$, where q is the domestic output and n is the number of pests domestically. The number of pests domestically, n, depends on the initial number of insects in the foreign country, N_0, the level of domestic control, x, and the level of foreign control, X. The percent of pests entering the domestic country through direct pest transfer on the foreign commodity, aQ_e, and through other pathways such as travelers, smuggling, and wind, ?, contributes to the final level of pests being equal to $n = N_0G(X)(? + aQ_e)g(x)$. Foreign pest level, N, is a function of the N_0 and X, such that $N = N_0G(X)$. $G(X)$ is the percent of pests left living in the foreign country after foreign control X, i.e., the inverse of a kill function. $g(x)$ is the percent of pests left living after domestic control, x. Both of these inverse kill functions are assumed to be negative and increasing ($G'(x)<0, G''(x)>0; g'(x)<0, g''(x)>0$). The marginal costs of producing both foreign output, Q, and domestic output, q, are assumed positive and increasing ($C_Q > 0, C_{QQ} > 0; c_q > 0, c_{qq} > 0$), and the marginal costs of the pest level are positive ($C_N > 0; c_n > 0$). The marginal impact of more pests on marginal production costs is assumed to be non-decreasing with the level of operation (C_{NQ} \$$0$; c_{nq} \$$0$).

Domestic consumer preferences are represented by an additively separable utility function $U(q + Q_e) + Z$ where $q + Q_e$ is domestic consumption of the homogenous agricultural good under consideration and is composed of both domestic production q and imports Q_e, and Z is the *numeraire* good. The marginal utility of consuming $q + Q_e$ is positive and declining ($U_q > 0,\ U_{qq} < 0$). Consumers have a budget constraint, $y=p(q+Q_e)+Z$, where p is domestic price and y is disposable income. An identical structure is used for the foreign consumers.

Individual consumers and producers consider n and N as given when determining their consumption and production choices. Domestic consumers choose $q + Q_e$ to maximize their utility, $u(q + Q_e) + y - p(q+Q_e) - ß(rx+sX)$. The variable, $ß$, is the proportion of the control expenditure the consumers pay.[5] rx is the total expenditure on domestic control. The domestic government provides sX as a subsidy for foreign control. Foreign consumers choose Q_d to maximize their utility $U(Q_d) + Y-PQ_d- B((R-s)X)$. P is the foreign market price; Y is foreign income; and B is the proportion of the control expenditure the foreign consumers pay. Domestic producers choose q to maximize profits, $pq - c(q,n) -(1-ß)(rx+sX)$, taking the number of pests as given. To sell in the domestic market, foreign growers pay for a quarantine treatment with a per unit cost of t.[6] Foreign producers choose Q_e and Q_d to maximize their profits: $(p-t)Q_e + PQ_d - C(Q_e + Q_d , N)- (1-\%)(R-s)X$. The total foreign expenditure on pest control is $(R-s)X$.

The market clearing conditions, the First Order Necessary Conditions (FONC), are:

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[5]If the pest control is financed by the government, tax revenues must be collected. In some circumstances, agricultural organizations contribute to these exotic pest exclusion and eradication programs.

[6]Under current regulations, quarantine treatments must satisfy a Probit 9 criterion, i.e., the treatment must eliminate 99.9986 percent of the insects. Thus, if a product has undergone an acceptable quarantine treatment, a should equal 0, i.e., there will be no or little pest migration directly on the foreign quantity, Q_e. If this is the case, $n = N_0G(X)(?)g(x)$.

$$
\begin{aligned}
p &= u'(q+Q_e) \\
P &= U'(Q_d) \\
p &= c_q(q,n(N_0,X,x,a,Q_e,?)) \\
p-t &= C_Q(Q_e+Q_d,N) \\
P &= C_Q(Q_e+Q_d,N)
\end{aligned}
\qquad \textbf{(1)}
$$

Solving the equations in (1) simultaneously results in the equilibrium prices and quantities. The competitive equilibrium is denoted as $q^*(T)$, $Q_e^*(T)$, $Q_d^*(T)$, $p^*(T)$, and $P^*(T)$ where $T = (N_0, X, x, a, ?, t)$. Using the implicit function theorem, the comparative statics of the market equilibrium are computed and presented in Table 1. For detailed derivations, see Lynch (1996).

As the direct (*a*) and other migration (*?*) of pests increases, the domestic quantity decreases and domestic price increases. With more pests domestically, *q* decreases as domestic growers' costs increase. The foreign country increases exports. As Q_e increases, Q_d falls, thus foreign price increases. Consumers in both countries are worse off while foreign producers are better off. Similarly, as domestic pest control increases, *q* increases, Q_e falls, and domestic and

Table 1. Competitive Equilibrium Comparative Statics

Equation variable	$\mathbf{q^*}$ domestic production	$\mathbf{Q_e^*}$ foreign exports	$\mathbf{Q_d^*}$ foreign consumption	$\mathbf{p^*}$ domestic price	$\mathbf{P^*}$ foreign price
Parameters					
Direct migration (a)	-	+	-	+	+
Other migration (?)	-	+	-	+	+
Initial pest level ($\mathbf{N_0}$)	?	?	?	?	?
Foreign pest control (X)	?	?	?	?	?

Domestic pest control (x)	+	-	+	-	-
Quarantine treatment (t)	+	-	+	?	-

foreign prices decrease. Domestic pest control benefits domestic growers and provides no benefit to the foreign country, shifting the comparative advantage in favor of the domestic growers. As foreign pest control increases, no prediction can be made about domestic and foreign quantities and prices. The foreign pest control benefits both the foreign and domestic producers. Fewer foreign pests decreases the likelihood of migration to the domestic country. However, since both growers benefit from fewer pests, either country's producers may benefit more. For example, if X decreases the foreign growers' costs more than the domestic growers', foreign producers will export more to the domestic country. As foreign commodities enter the domestic market, domestic price will decrease and domestic growers will produce less. Alternatively, the domestic growers benefit more therefore domestic production increases relative to foreign exports. Interestingly, as the initial level of pests increases, no inferences can be made about market quantities and prices. An increase in the level of initial pests results in an increase in the effectiveness of the pest control measures initially. However, although pest control is more effective, there finally may still be more pests. Therefore, exports may increase or decrease and may result in more or less pest migration. Again the relative change in the costs of the foreign and domestic producers determines the impact on domestic quantity and thus the domestic and foreign prices. If the quarantine treatment cost increases, the domestic quantity will increase as the exports fall. The foreign price will decrease as the quantity sold in the foreign market increases. The effect on the domestic price is ambiguous as it is affected by both the increased domestic quantity and decreased exports. The relative changes in quantities will determine the overall effect on domestic price.

Free-Trade Solution

Under the free-trade scenario, growers act with no government intervention. Growers determine the level of pest control and pay for it. In each country, the growers select what is optimal for their own production costs, disregarding the fact that the foreign control level affects the domestic level of pests. Since a competitive market situation is assumed, the growers take price as given and do not behave strategically to keep the price high. New growers could enter the market or foreign growers could increase their exports. In addition, growers in both countries ignore that pest control may have negative environmental effects. Environmental effects are a function of pest control level, *h(x)*, with increased levels increasing environment damage *(h'(x)>0)*.[7] These environmental effects can be seen as another market failure and are not included in the free trade solution of pest control. For simplicity, the *'s that indicate the optimal function values are omitted. Domestic and foreign growers solve:

$$Max \quad \text{p} \; ' \; p(?)q(?)\&c(q(?),n(N_0,X,x,Q_e(?),\text{a},?))\&rx\&sX \qquad \textbf{(2)}$$

$$Max \quad ? \; ' \; P(?)Q_d(?)\%(p(?)\&t)Q_e(?)\&C(Q_e(?)\%Q_d(?),N)\%RX \qquad \textbf{(3)}$$

Under this scenario, the equilibrium control and subsidy levels are determined by the FONCs:

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[7] If exotic species were not controlled, disruptions to the ecosystem that have negative impacts on societal welfare may result. In this paper, however, the externalities are assumed to be directly connected to the control measures. Some control measures such as sterile insect release have no negative environmental or health effects (USDA- APHIS, 1999a). More details on the environmental effects are provided in the description of the program, provided later in the paper.

$$-\frac{\partial c}{\partial n}[N_0 G(X)(?+\alpha Q_e)g'(x)+N_0 G(X)\alpha\frac{\partial Q_e}{\partial x}g(x)] = r$$

$$-\frac{\partial C}{\partial N}[N_0 G'(X)] = R$$

The domestic and foreign growers will conduct pest control until the reduction in marginal cost using one more unit of pest control is equal to the per unit cost of pest control. The domestic marginal cost has two components: how the level of pest control directly affects the level of the domestic pests and thus the marginal costs, and how the level of pest control affects the import level and thus the potential pest migration. As mentioned above, the growers do not consider any negative externalities (*h(x)* and *H(X))* that may result from using the control mechanisms. Thus, growers may use more pest control than is socially optimal. However, in the scenarios examined below, the governments pay part of the pest control cost. In this case, the growers are paying the full cost of the control; therefore they may use less pest control than with government intervention.

The domestic growers cannot impose an import ban to stop direct migration with the commodity, i.e., domestic growers cannot set Q_e (thus aQ_e) equal to zero. If they could, domestic price would increase as imports decreased to zero, domestic quantity would rise, and foreign consumption would increase and foreign price would decrease. In the domestic country, the direct migration of the pests would fall to zero. The FONC becomes $\frac{\partial c}{\partial n}[N_0 G(X)?g'(x)] = r$.

Under a free trade scenario, the domestic growers would have to pay for the subsidy. However, subsidizing the foreign growers may lower foreign costs and improve their comparative advantage vis-a-vis the domestic growers. This would make foreign products more competitive. Therefore, no subsidy is given.

The free trade solution may be sub-optimal. Less foreign control may be conducted and more pests may migrate to the domestic production areas than is optimal from a domestic welfare viewpoint. The introduction of exotic pests would increase the level of domestic pest control, which has environmental externalities. Foreign growers do not consider the impact of their pest control on domestic pest levels, thus may not conduct enough pest control.

Government Problem

Given the public good aspect of the exotic pest problem and the environmental externalities, governments often intervene to maximize their country's welfare. In this model, the domestic government takes the market clearing conditions in (1) as given and chooses the pest control level, x, and the subsidy levels to give the foreign government,[8] s, and whether to impose an import ban to maximize the country's welfare. The government pre-commits to a specific policy intervention that cannot be altered even if it is sub-optimal ex-post, i.e., once the farmers choose their output levels and consumers their consumption levels. The decision of whether to impose the import ban is determined by comparing the welfare with a ban ($s = 0$) to the welfare without a ban ($s = 1$). The ban will have three discrete effects: it alters the level of controls used and thus the level of pests and the environmental effects, it changes the price of the commodity and therefore consumer surplus, and it impacts the domestic production of the commodity. These changes may move in opposite directions to affect domestic welfare. As above, environmental effects are a function of pest control level, $h(x)$, with increased levels increasing environment damage

[8] A subsidy can be viewed as any type of assistance to control pests. Although governments do provide monetary assistance to other governments, they also provide management, technical and equipment assistance. Governments have also cooperated on joint research projects.

(h'(x)>0), but are now considered explicitly. For simplicity, the *'s that indicate the optimal function values are omitted.

Under a Cournot behavior assumption, the domestic government conjectures that when it changes domestic pest control, the foreign government will hold its level fixed. Thus the government maximizes society's welfare by choosing x, s and s as given by equation (5)

$$\begin{aligned} Max \quad w \ ' \ \ & s\,[p(?)q(?) \& c(q(?),n(N_0,X,x,Q_e(?),a,?)) \% \\ & u(q(?) \% Q_e(?)) \% y \& p(?)q(?) \& p(?)Q_e(?) \& sX \& rx \& h(x)] \% \\ & (1 \& s\,)[p(?)q(?) \& c(q(?),n(N_0,X,x,?)) \% u(q(?)) \% \\ & \quad y \& p(?)q(?) \& sX \& rx \& h(x)] \end{aligned} \qquad \textbf{(5)}$$

The government is maximizing consumer and producer welfare minus the cost of conducting domestic pest control (rx) and subsidizing foreign pest control (sX). It also has a choice of imposing an import ban on the foreign country ($s\ =1$) or permitting imports ($s=0$). If the government weighs consumers, producers and the environmental effects equally, the welfare maximization problem (5) can be reduced to (6):

$$
\begin{aligned}
Max\ w \ = \ & \sigma[-c(q(?),n(N_0,X,x,Q_e(?),\alpha,?)) \\
& + u(q(?)+Q_e(?))+y-p(?)Q_e(?)-sX-rx-h(x)] \\
& +(1-\sigma)[-c(q(?),n(N_0,X,x,?))+u(q(?))+y-sX-rx-h(x)]
\end{aligned}
\tag{6}
$$

The FONC with respect to x of (6) is:

$$
\begin{aligned}
& \sigma[u'[\frac{\partial q}{\partial x}+\frac{\partial Q_e}{\partial x}]-p\frac{\partial Q_e}{\partial x}-Q_e\frac{\partial p}{\partial x}-c_q\frac{\partial q}{\partial x}- \\
& c_n[\frac{\partial n}{\partial x}+\frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x}]-r-h'(x)] \\
& +(1-\sigma)[u'\frac{\partial q}{\partial x}-c_q\frac{\partial q}{\partial x}-c_n\frac{\partial n}{\partial x}-r-h'(x)]=0
\end{aligned}
\tag{7}
$$

By (1), several elements in (7) cancel each other out and the FONC is:

$$
\sigma(-Q_e\frac{\partial p}{\partial x}-c_n\frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x})-c_n\frac{\partial n}{\partial x}-h'(x)-r=0
\tag{8}
$$

If $\sigma=1$ and imports are permitted, the domestic government considers the import-weighted price effect of increased pest control, the marginal cost effect, the marginal effect on the environment, and the direct cost to the taxpayers when deciding the level of pest control to apply. The government takes into account how the level of pest control will change the price and how the price change affects welfare. The marginal cost has two parts: the direct effects of pest control on the domestic pest population and the indirect effects through the change in the level of imports (as x increases, Q_e decreases) and thus the change in the number of migrating pests. As the government is playing Cournot and thinks it cannot influence the foreign control decisions, it picks a subsidy level of $s = 0$. The FONC for s is $-X = 0$. If the government chooses to use an import ban and sets $s = 0$, the optimal level of pest control is chosen such that

$$-c_n \frac{\partial n}{\partial x} - h'(x) - r = 0 \tag{9}$$

From (9), one sees that a marginal increase in pest control will reduce producers' costs. The government will conduct pest control until the per unit costs and marginal environmental effects equals the reduction in producer costs. It will use less pest control than the free market solution under an import ban because it considers the marginal negative impact on the environment. This will increase the welfare of society relative to the free market solution which disregards the externality. To compare the level of the pest control between the two discrete situations, the domestic government picks the optimal level of Q_e in (6) and then compares it to the import ban level of $Q_e = 0$. The optimal level of the imports from (6) will solve the FONC:

$$-c_n \frac{\partial n}{\partial Q_e} - \frac{\partial p}{\partial Q_e} Q_e = 0 \tag{10}$$

Imports have two effects on domestic welfare. First, if the foreign country has no pests, i.e., $N_0 = 0$, $N_0 G(X) = 0$, or $a = 0$,[9] permitting imports increases domestic welfare by decreasing the price (weighted by the level of imports). However, if $a > 0$, allowing imports to enter the domestic market could decrease welfare by increasing the pest population and domestic marginal costs. The overall change in welfare of permitting imports depends on the magnitudes of these two effects. If the marginal change in production

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[9] If $a = 0$, no pest will enter with the commodity. This assumes that all quantities of the commodity follow the quarantine procedure and the quarantine treatment is 100 percent effective.

costs of more pests is always greater than the price change, the domestic country will set Q_e to zero, i.e., impose an import ban. If the effect on costs is less than the effect on price, imports are permitted until the change in costs equals the change in price. The level of pest control with and without a ban can be compared. Substituting equation (10) into (8), the optimal level of control with imports depends on the magnitudes of the change in domestic price due to the increase in pest control and change in price due to the change in import quantity. If $\frac{\partial p}{\partial x} > \frac{\partial p}{\partial Q_e}\frac{\partial Q_e}{\partial x}$, more pest control will be conducted with imports than in the case without imports. If $\frac{\partial p}{\partial x} < \frac{\partial p}{\partial Q_e}\frac{\partial Q_e}{\partial x}$, less pest control will be conducted than without imports. The substitution of the market clearing conditions into the welfare equation provides $x = \hat{x}(X, N_0, a, ?, t, r, s)$, the domestic country's reaction function.

The foreign country maximizes its welfare given the market equilibrium condition and the domestic country's choice of σ by choosing X:

$$\begin{aligned} Max \quad W = \sigma\,[\, & P(?)Q_d(?) + (p(?) - t)Q_e(?) - C(Q_e(?) + Q_d(?), N) \\ & + U(Q_d(?)) + Y - P(?)Q_d(?) - (R - s)X - H(X)] \\ & + (1 - \sigma)[P(?)Q_d(?) - C(Q_d(?), N) + \\ & U(Q_d(?)) + Y - P(?)Q_d(?) - (R - s)X - H(X)] \end{aligned} \qquad \textbf{(11)}$$

or as simplified

$$\begin{aligned} Max \quad W = \; & \sigma\,[(p(?) - t)Q_e(?) - C(Q_e(?) + Q_d(?), N) + \\ & U(Q_d(?)) + Y - (R - s)X - H(X)] + \\ & (1 - \sigma)[-C(Q_d(?), N) + U(Q_d(?)) + Y - (R - s)X - H(X)] \end{aligned} \qquad \textbf{(12)}$$

The simplified FONC with respect to foreign control level, X, is:

$$\sigma\, Q_e \frac{\partial p}{\partial X} - C_N \frac{\partial N}{\partial X} - (R - s) - H'(X) = 0. \qquad \textbf{(13)}$$

If $s = 1$, the equilibrium X is determined by an export-weighted domestic price effect, the decrease in marginal cost to foreign producers of fewer pests, the marginal effect on the foreign environment, and the per unit cost of the pest control minus any subsidy given to the foreign government. Given that foreign pest control decreases potential pest migration, an increase in X may raise the production in the domestic country. As q increases, the domestic price will decrease, which makes the export market less desirable to foreign producers. This effect is included in $Q_e \frac{\partial p}{\partial X}$, which has an ambiguous sign.[10] Alternatively, if there are more exports, there could be a higher pest migration, which causes domestic costs to increase. If the domestic country institutes an import ban, $s = 0$, then the FONC becomes:

$$-C_N \frac{\partial N}{\partial X} - (R - s) - H'(X) = 0 \qquad \textbf{(14)}$$

The foreign control effect on the domestic pest population is not considered. The foreign government determines pest control level by equating the decrease in the marginal cost for foreign producers to the marginal environmental effects and the per unit cost minus the per unit subsidy for pest control. The solution to (14) is the foreign country's reaction function, $X = \hat{X}(x\ N_0, a, ?, t, R, s, s\ )$. The level of foreign pest control can increase or decrease when the price effect is not considered. The incentive to control pests may decrease when the export market is closed due to an ban.

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[10]

$$\frac{\partial p}{\partial X} = \frac{u''(q)U''(Q)[C_{QN} N_0 G'(X)(c_{qq} - c_{qn}\frac{\partial n}{\partial Q_e}) + c_{qn}\frac{\partial n}{\partial X} C_{QQ}]}{(-)}$$

The comparative statics of the equilibrium of this non-cooperative game for the two choice variables, x and X, are derived. All the comparative statics have ambiguous signs.[11] One cannot tell how domestic pest control will change as foreign pest control changes, as the initial level of the pests increases, or as the direct or other migration of the pest population alters. Even for parameters like the cost of the control measures or the imposition of an import ban, one finds the pest control can change in either direction due to the interdependence of the two markets and the migration of the pests. Therefore, if countries act independently, policymakers need to evaluate whether a certain policy such as an import ban will increase their country's welfare in each exotic pest situation. No one policy will increase welfare in all cases of exotic pest threat.

[11]For detailed derivations, see Lynch (1996).

Cooperative Solution

If each of two countries recognizes that the other's pest control level affects its welfare, they might agree to cooperate. Equation (15) depicts the joint welfare-maximization equation where the countries jointly choose x and X :

$$\begin{aligned} Max \;\; w + W = \; & \sigma[-c(q(?),n(N_0,X,x,Q_e(?),\alpha,?)) + u(q(?)+Q_e(?)) \\ & + y - rx - h(x) - tQ_e(?) - C(Q_e(?)+Q_d(?),N) + U(Q_d(?)) + Y - RX - H(X)] \\ & + (1-\sigma)[-c(q,n) + u(q) + y - rx - h(x) - C(Q_d,N) \\ & + U(Q_d) + Y - RX - H(X)] \end{aligned} \tag{15}$$

The two countries will set their joint pest control quantities given the following two FONCs:

$$\begin{aligned} & -\sigma c_n \frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial x} - c_n \frac{\partial n}{\partial x} - r - h'(x) = 0 \\ & -C_N \frac{\partial N}{\partial X} - \sigma c_n \frac{\partial n}{\partial Q_e}\frac{\partial Q_e}{\partial X} - c_n \frac{\partial n}{\partial X} - R - H'(X) = 0 \end{aligned} \tag{16}$$

Under cooperative welfare maximization, domestic pest control decreases relative to the non-cooperative Nash equilibrium. The cooperative foreign pest control can be greater or smaller than the non-cooperative level, as a marginal increase in foreign control expenditure has a cost-reducing effect in both countries. If the two governments choose to implement an import ban, the FONCs revert to (9) and (14) with the addition of the direct effect of foreign control on domestic marginal costs ($-c_n \frac{\partial n}{\partial X}$). While it seems counterintuitive to impose an import ban, if the joint welfare is maximized without permitting trade, it may be the policy decision. Operationally, in this case, the governments would determine how to share the joint costs *(rx+RX).* If the domestic government is willing to bear a large percentage of the cost of foreign control, the foreign government may agree to the import ban.

Purchasing Foreign Pest Abatement

To influence the foreign control level without joint welfare maximization, the domestic country can act as a Stackleberg leader. The domestic country takes the foreign country's reaction to the domestic level of control and the subsidy, $\hat{X}(x,s)$, and determines the level of subsidy it must give the foreign country to maximize domestic welfare. In this case, the FONCs for the optimal levels of pest control and subsidy are :

$$\begin{aligned} &-\sigma Q_e[p_n(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})+p_N(\frac{\partial N}{\partial x}+\frac{\partial N}{\partial X}\frac{\partial X}{\partial x})] \\ &-\sigma c_n[Q_{en}(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})+Q_{eN}(\frac{\partial N}{\partial x}+\frac{\partial N}{\partial X}\frac{\partial X}{\partial x})] \\ &-c_n(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x})-r-s\frac{\partial X}{\partial x}-h'(x)=0 \end{aligned} \quad \textbf{(17)}$$

$$\begin{aligned} &-\sigma Q_e[p_n\frac{\partial n}{\partial X}\frac{\partial X}{\partial s}+p_N\frac{\partial N}{\partial X}\frac{\partial X}{\partial s}]-\sigma c_n[Q_{en}\frac{\partial n}{\partial X}\frac{\partial X}{\partial s}+Q_{eN}\frac{\partial N}{\partial X}\frac{\partial X}{\partial s}] \\ &-c_n(\frac{\partial n}{\partial X}\frac{\partial X}{\partial s})-X(s)-s\frac{\partial X}{\partial s}=0 \end{aligned} \quad \textbf{(18)}$$

The government chooses a level of domestic pest control so that the import-weighted price effect, the marginal cost effect, and the negative environmental effect equals the per unit cost of pest control and the marginal impact on the subsidy for foreign pest control of more (less) domestic pest control. Acting as a Stackelberg leader, the domestic government considers how domestic control affects the level of the foreign control when maximizing welfare. The optimal subsidy level for foreign pest control is the level at which the benefits to domestic producers of reduced pest migration (through lower marginal costs) equals the cost of the subsidy.

If the domestic government decided to ban imports, then it chooses the optimal level of pest control and subsidization to satisfy the following FONCs:

$$-c_n\left(\frac{\partial n}{\partial x}+\frac{\partial n}{\partial X}\frac{\partial X}{\partial x}\right)-r-s\frac{\partial X}{\partial x}-h'(x)=0 \qquad \textbf{(19)}$$

$$-c_n\left(\frac{\partial n}{\partial X}\frac{\partial X}{\partial s}\right)-X(x,s)-s\frac{\partial X}{\partial s}=0 \qquad \textbf{(20)}$$

Given an import ban, the domestic government sets the optimal level of pest control where the change in marginal costs and the change in the cost of the subsidy equals the per unit cost of the domestic control and the marginal environmental effects. While a price increase or decrease will have distributional impact, i.e., it will be gained either by domestic producers or consumers, the government does not consider the price effect, as it does not change domestic welfare if no trade is permitted. When deciding the subsidy, the domestic government considers how a marginal increase in foreign pest control affects domestic producers' marginal costs, the actual level of foreign control and how an additional unit of subsidy increases the cost of the subsidy.

Graphical Analysis

Some of the results of the theoretical model can be seen graphically. A graphical analysis depicts how domestic and foreign welfare changes if an import ban is imposed. These changes depend on how the production costs change due to the pest population, thus how the domestic supply curve shifts. In Figure 1, the domestic (importing country) and foreign (exporting country) demand and supply curves are given. The domestic country is assumed to have an initial pest level of zero, n_0. The domestic market is larger than the foreign market. Foreign producers have lower costs of production but have positive levels of the pest. If the domestic government imposes an import ban to exclude the exotic pest, domestic welfare is *zyb*. The domestic price is p_0 and domestic quantity is q_0 . Consumer surplus is zyp_0 and producer surplus is byp_0. The foreign market price, P_d, is lower than p_0 at point *i*. Foreign consumer surplus is *gni* and producer surplus is *niv*. Under an import ban, foreign production and consumption equals Q_o. If the import ban is lifted and few or no pests migrate to the domestic country, the domestic consumer surplus increases to zcp_1 as the quantity consumed increases to $q+Q_e$ and price falls to p_1. Domestic producer surplus decreases to bep_1 and domestic quantity decreases from q_0 to q_1. Foreign consumer surplus decreases to grp_1 as price increases to p_1 and quantity consumed decreases from Q_o to Q_d. Foreign producer surplus increases to hvp_1 as quantity produced increases from Q_o to Q_t. Q_t-Q_d is the amount exported, Q_e.. This depicts the standard trade result when no externalities exist of free trade benefitting domestic consumers due to the higher quantity and lower price. Domestic producers, on the other hand, prefer the import ban because they produce more and receive a higher price. This standard result changes if pests migrate into the domestic country's production regions through this trade.

Figures 2 and 3 present two situations where pests do migrate to the domestic country with the foreign imports. The two figures present different outcomes from the exotic pest migration. In Figure 2, where imports are permitted, the total supply available in the domestic market increases. Price decreases from p_o to p_1 . However, the pest population also increases with imports causing domestic costs to increase. The increased cost causes the domestic supply curve to shift left from *DS* at $n=0$ to *DS* n_1. Thus the final supply in the domestic market with the imports is represented by $Supply(n_1)$. The final price is p_1'. In Figure 2, the welfare change for domestic consumers by removing the import ban is still positive, and surplus increases from zyp_0 to zcp_1 '. The domestic producer surplus falls from byp_0 to sep_1 ' for two reasons: they now have competition from imports, so domestic quantity decreases from q_o to q_1, and they have increased costs due to the pest population, which decreases quantity further from q_1 to q_1'. Foreign consumers lose as their price increases from P_d to p_1 ' and quantity sold decreases from Q_0 to Q_d. Foreign producers increase production from Q_0 to Q_t and receive a higher price p_1 ' instead of P_d. Foreign producer welfare increases from vnP_d to vhp_1 '.

However, Figure 3 demonstrates how both domestic producers and consumers can lose by permitting imports. Imports are permitted and increase the domestic pest level. As the pest population increases, the cost of production increases for the domestic producers, thus the domestic supply curve shifts from $DS\ n=0$ to $DS\ n_1$. Domestic production decreases q_0 to q_1 and price rises to p_1', which is higher than p_0, the price when there was no trade. Since domestic producers were the major suppliers, their decreased production causes consumer welfare to fall under free trade from zyp_0 to zcp_1. The exotic pests increase costs and decrease quantities to the point that the quantity available post-trade (q_1+Q_e) is less than q_0. Domestic producer surplus decreases from byp_0 to sep_1 . In Figure 3, the producers have larger losses from the increased per unit production costs (due to the increased pest population) than from the import competition. If the pests migrate only on the imports (a >0 and ?=0), an import ban would be the optimal policy to maximize domestic producer and consumer surplus. On the other hand, if pest migration occurs regardless of import restrictions (?>0), the domestic producers may prefer decreasing foreign pest populations to decrease the probability of migrating. If the higher price in the domestic market provides foreign producers with a greater incentive to control their pest populations and a =0 , then domestic producers may advocate open borders even though free trade results in market competition.

Besides the increased production costs incurred from exotic pest introduction, domestic growers may lose their export markets due to import bans imposed by other states or countries. Figure 4 depicts a demand contraction which may occur in the importing country if an exotic pest is introduced into one of the production regions; for example, Texas is banned from shipping to California when Mexican Fruit Flies are found in the Lower Rio Grande. The pest's introduction changes the host status of a production region. If demand contracts, domestic producer surplus decreases from byp_0 with no trade to sep_0 after the pest introduction. The consumers surplus under no trade was zyP_0. After the demand contraction and the increased production costs, domestic consumer welfare decreases to lcp_0. The domestic consumers in the unrestricted area are not negatively affected as the price has not increased (the price could increase or decrease depending on the magnitude of the demand contraction and supply change) . However, the consumers who live in the production regions or countries where the import bans against the infested region have been imposed have a decrease in welfare of *zycl*.

Background Information and Current Programs

The U.S., through the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS), follows a basic pest protocol to deal with exotic pests and protect the U.S. agricultural producers, other citizens, and the ecosystems. The protocol is a three-pronged approach: exclusion, detection and prevention, and eradication. As trade and travel increases, U.S. efforts alone were proving less successful at preventing the introduction of exotic pests. For example, since 1992, California Department of Food and Agriculture has reported 67 new pest invaders that have become established in the state (Coppock and Kreith 1999). Thus, U.S. officials have increased cooperative efforts with Mexican and other Central American countries to decrease the number of pests that arrive at the border location. Cooperative efforts have been expanding on two of the most economically significant insect pests, the Mediterranean Fruit Fly (Medfly) and the Mexican Fruit Fly (MFF).

The MFF hosts on 40 different agricultural commodities. It has been trapped each year in the Lower Rio Grande Valley of Texas and since the early 1980s periodically in California. It has colonized almost all of Mexico. It was first trapped in Tijuana in 1953 and now has been found in Tecate and Mexicali. A strong flier, MFF infests citrus groves by migrating across Mexico's northwestern border or with infested fruit (USDA APHIS 2000).

The Medfly hosts on more than 200 different fruits, flowers, vegetables and nuts. It can be transported from one area to another in a few hours as an adult or as a larva in fruits or vegetables. All of Central America except for Mexico and Belize has a Medfly population. It has been trapped in the U.S. 21 times since 1929 (USDA APHIS 2000). Approximately 80 percent of the U.S. citrus production will be affected if the Medfly should become established.

In 1996-97, U.S. citrus production was 4.7 million tons for fresh use and 12.5 million tons for processed use, with a value of $2.4 billion (USDA NASS 1999). Mexico shipped more than 5,230 metric tons of oranges to the U.S. in 1997, valued at $3 million. The impact of Mexican citrus to U.S. price is small overall, although in certain markets during certain months Mexican citrus can influence the price. Other commodities such as mangos are not grown in the U.S. so domestic producers are affected only through substitution effects. U.S. fruits and vegetables that would be impacted by establishment of one or both of the flies include apples, apricots, avocados, bell peppers, cherries, dates, figs, grapefruit, grapes, kiwis, lemons, tangerines, oranges, nectarines, peaches, pears, plums, and fresh tomatoes (Siebert 1990, Grimes 1992). Overall, commodities threatened by these insect pests would not be affected a great deal by increased import competition. During specific market windows, increased Mexican imports will decrease the price.

Estimated Costs of Establishment in the U.S.

If the Mexican Fruit Fly (MFF) is established and no control conducted, crop loss in the 12 most affected crops is estimated to be 20 percent of the yield (Grimes, 1992). Citrus growers would control MFF damage by using twelve or more applications of Malathion applied by air and ground per year. Even with these control measures, Grimes (1992) estimates that yields for these 12 crops will decrease 5 percent. This crop loss has an estimated value of $116.5 million (Grimes, 1992). The decrease in yield stems from both direct damage from MFF and from secondary pest outbreaks that may occur from the use of Malathion. The cost of the additional pesticide applications is estimated to be $500,000. To ship to other markets, U.S. growers will be required to follow export markets' quarantine protocols. If the quarantine cold treatment method is used, the potential trade costs is estimated to range from $28 to $43 million. Without including any of the costs from the environmental impact of using these additional pesticides, losses to consumers are more than $489 million each year. The overall net welfare change is estimated to be $346 million. In addition, urban home owners would be expected to use 2 million pounds of Malathion to maintain their gardens and fruit trees (Dowell and Krass, 1992).

Annual economic losses to the U.S. economy are expected to be $1.5 billion (Nichols 2001) if the Medfly is established in the U.S. The cost of pesticide materials and application in California would be approximately $27.2 million per year for the 1.7 million acres treated. The cost of Medfly establishment ranges from $155 to $341 million per year for California (Coppock and Kreith, 1999). If quarantine treatments such as methyl bromide fumigation were required by Asian export markets, the cost of the treatments and the product lost due to phytotoxicity is estimated to be $169 million. California output would be reduced $538 million, income would go down by $283 million, and 7,900 jobs in the state would be lost. People who had fruit trees or grew produce in their own garden would also suffer losses. In addition, the growing organic farming sector may find that the Medfly caused sufficient damage to render organic production practices unprofitable (Siebert 1990).

In another study, Medfly establishment in California was predicted to cost nearly $1.6 billion a year in crop loss and treatment (California Agriculture 1999). If foreign markets placed quarantines on California fruit, the State would lose 35,000 jobs and output would be reduced by $3.5 billion. If other U.S. states quarantined California fruit as well, job losses would be 132,000 with a $13.4 billion loss in economic activity (USDA APHIS 2000).

Environmental Effects of Control and Establishment

In addition to the cost and yield changes, there would be environmental impacts in the production regions where the MFF and Medfly are detected and established. Some control practices have minimal environmental effects. For example, mass trapping, fruit stripping, and sterile insect release have relatively minimal environmental impacts (USDA APHIS 1999a). These techniques however have not been effective at eradicating an exotic pest population, if that is an area's objective. Aerial Malathion bait and the fumigant soil treatments (chlorpyrifos, diazinon, and fenthion) are expected to have significant environmental impacts, particularly on biological resources. Ground application of Malathion has less impact but may be physically difficult due to a region's terrain and landuse patterns, and is more expensive. While these environmental effects are discussed in the context of an eradication program, they will also be present if individual growers use chemicals to control the fruit flies following establishment. Establishment will result in chemical applications each year rather than for a single eradication program period. Typical Medfly eradication programs use two to four aerial applications followed by sterile insect release (over a single growing season, a citrus grower could use 12 applications). In one eradication program in Northern California in 1980-1982, however, 30 applications were used. Malathion kills not only the Medfly and MFF but also beneficial insects. The disruption of biological control measures and secondary pest outbreaks occurred following the Californian eradication campaigns (Ehler and Endicott, 1984). Residues from Malathion bait sprays were found as far away as 12 miles in high winds. With lower wind speeds, residues were predicted to be 3.5 miles from the treatment area. Thus Malathion's effects may extend beyond the treatment area.

Malathion is not considered a high risk chemical for humans unless one eats contaminated vegetation. All the potential soil treatments though are considered moderately or severely toxic to humans and other mammals. All terrestrial and aquatic invertebrates will have significant population decreases if contact is made with Malathion and the fumigant soil treatments. Dahlsten, Garcia and Lorraine (1989) found the impact of Malathion includes total eradication of flies, caterpillars and wasps, decreased population of beneficial insects, and secondary pest outbreaks. Malathion use in the Lower Rio Grande Valley, for example, could eliminate 26.1 percent of the shrew population, 46 percent of the toads, 62 percent of the tree frogs and almost 100 percent of the terrestrial invertebrates that come in contact with the chemical.[12] Other species may be affected due to decreases in the food supply (USDA APHIS

[12]Terrestrial invertebrates include earthworms, dragonflies, grasshoppers, lacewings, flies, ants, honey bees and wasps.

1999a). Potential contamination of surface water and groundwater resources by pesticides could pose a hazard to both wildlife and human populations (USDA APHIS 1999a).

Exclusion

Because both the economic losses and the environmental impacts can be significant, the first goal of the U.S. government is to prevent an exotic pest from entering the U.S. borders. The U.S. has used historically quarantine protocols, import bans, and inspections to accomplish this goal.

Quarantine Protocols

Inspections for exotic pests are conducted at border crossings. With MFF and Medfly, however, imports can contain unhatched eggs or larvae; therefore, external inspection at the border may not be fully effective. Thus, unless a foreign country has no population of the exotic pest, it must follow some type of quarantine protocol which can raise costs and affect the quality of the product. These quarantine treatments must meet the Probit 9 criterion: guarantee that 99.9986 percent of the insects have been eliminated. This criterion is difficult to meet and research on acceptable treatments is ongoing. Methyl bromide fumigation is approved by APHIS for citrus, but can cause fruit losses up 60 percent which makes it an economically unacceptable treatment (Citrograph, 1992). The cost of methyl bromide treatment is $12 per ton of citrus (Carpenter, Gianessi, and Lynch 2000). It also is being regulated under the Clean Air Act and the Montreal Protocol due to its ozone-depleting characteristic.[13] Cold storage is an approved treatment but can cause chilling injury to citrus fruit. High temperature forced air treatment can also be used but costs about $120 per ton. Because of the cost and damaging aspects of many of the quarantine treatments, most

[13]When the regulations banning the production and importation of methyl bromide in the U.S. after January 1, 2001, were harmonized with the Montreal Protocol, quarantine uses were exempted from the phaseout schedule.

growers advocate for pest-free status. With pest-free status, the quarantine treatment is waived or less stringent.

Inspections

Inspections are conducted on approximately 2 percent of products entering from a country known to harbor the exotic pests (Sills 2001, OTA 1993). These inspections increase crossing time and gridlock at the border for both produce shippers and travelers, which can increase air pollution. The fees and inspection costs can increase the price of imported goods. Although the APHIS standard is to inspect all perishable cargo within 3 hours of its arrival, with the increases in trade, it is difficult to conduct a quality inspection in this time frame. Complying with these regulations can be costly, inconvenient, and time-consuming. In fiscal year 2000, APHIS contributed $9 million and cooperators (states and other countries) contributed $114 million for agricultural quarantine inspections for both animals and plants. Users paid fees of $194.6 million for inspection services.

Even with these inspections and strict quarantine regulations, however, the Office of Technology Assessment (1993) determined that the existing U.S. policies designed to prevent the introduction of harmful invasive species were not maximizing the nation's welfare. It found that the U.S. approach is piecemeal, lacks adequate rigor and comprehensiveness, and is unable to keep pace with new pathways and pest introductions. Similarly, a GAO report (1997) suggested that the increasing number of travelers and trade had exceeded the inspection system used by USDA APHIS even though funding had been increased. Between 1988 and 1993, six new border crossings were established along the U.S. and Mexico border (GAO, 1997). In 1999, two new U.S. and Mexico border facilities were opened to conduct cargo, passenger, and pedestrian inspections. Since 1990, imports and exports have increased more than 30 percent, while passenger traffic has doubled in volume (USDA APHIS, 1999a). In 1998, USDA inspectors intercepted more than 52,000 items containing plant pests and diseases identified as economically significant to the U.S. agricultural sector (USDA APHIS 1999a). Along the Mexican border, inspections of passenger vehicles may occur for less than 0.1 percent during high-volume time, rather than for the USDA standard of 2 percent of vehicles. There is also limited coverage of the pedestrian crossings (GAO, 1997). Difficulties exist in determining the importance of these inspections. While interceptions are increasing, smuggling also appears to be higher. The cost of these inspections has become more fully the importers' responsibility through user fees.

Border Cargo Release Program

Given the time lags at the border, the U.S. has worked with Mexico to develop new programs that ensure pest exclusion while at the same time facilitate trade. For example, APHIS has introduced the Border Cargo Release (BCR) program along the Mexican border to reduce the inspection of high-volume, non-host commodities such as tomatoes, squash and bell peppers. At Nogales, Arizona/Mexico, about 75 percent of the produce in 1995 was permitted into the U.S. through the BCR program (GAO, 1997). To qualify, no more than one exotic pest can be found on the commodities in a 1-year period, or no more than three harmful pests found over a 6-year period. This program benefits Mexican growers by decreasing the time to cross the border, and U.S. consumers obtain fresher, low-cost winter produce with only a small increase in risk. Concerns remain about smuggling high-risk commodities in these low-risk shipments.

Preclearance Programs

California has imposed an import ban several times over the years when Mexican-grown citrus and mangos were found to be infested with MFF (Citrograph 1986). Although quarantine protocols existed, concerns were raised that these had not been followed. In response, APHIS introduced pre-clearance programs in Mexico (and 27 other countries). The pre-clearance program, which is fully funded by the Mexican government and growers, has APHIS staff supervise the quarantine protocol at the origin of the commodity. APHIS staff is present when Sanidad Vegetal (the Mexican enforcement agency) cuts and inspects the fruit prior to fumigation. If the lots are infested, APHIS and Sanidad Vegetal reject them and the growers and/or shippers are saved the cost of fumigation and shipment to the border. As pests are kept further from the border area, U.S. growers benefit from decreased migration probabilities. The fumigation process itself is monitored by APHIS staff. Sanidad Vegetal ensures the shipments are sealed to prevent any co-mingling with non-treated fruit. Border inspectors can reinspect the shipment but pre-cleared shipments have a lower probability of being inspected and rejected (Sills 2001). Mexican growers benefit from the decreased time in crossing the border. Mexican shippers have found that pre-clearance certification is a "badge of approval" that can be used as a marketing tool to promote their products (Sills 2001).

Detection and Prevention

In addition to exclusion activities, the U.S. and Mexico attempt to detect infestations while pest numbers are still small and geographically concentrated enough to eliminate. Regions conduct systematic and periodic visual surveys and annual detection trapping programs. The U.S. spent $6.7 million on pest detection activities in 2000 (USDA APHIS 2001). While all 50 states can be impacted by the introduction and establishment of different species of fruit flies, seven eco-regions face the greatest threat for geographic, demographic, climatic and cropping reasons (USDA APHIS, 1999a). Detection efforts are therefore concentrated in these areas. They include the California Central Valley and Coastal Region, Southwestern Basin and Range, Lower Rio Grande Valley, Southeastern and Gulf Coastal Plain, Mississippi Delta, Florida, and the Marine Pacific Forest.

USDA and these areas cooperate through the National Exotic Fruit Fly Detection Program. The trapping programs seek to detect new infestations of fruit flies before the infected area exceeds one square mile in urban areas and 50 square miles in rural areas. USDA asks states to pay for half of the costs of these program. The federal government, California, Texas and Mexico cooperate on an MFF detection and eradication program in northwest and northeast Mexico. Sanidad Vegetal, APHIS, and Mexican producers monitor and control MFF along the U.S.-Mexico border to reduce the risk of infestation in southern California and the Texas Rio Grande Valley. APHIS and Sanidad Vegetal also assist with surveillance, integrated pest control and regulatory activities to help maintain a pest-free region in Baja California, Baja California Sur, Sonora and Chihuahua. These programs include trapping activities, sterile fly releases, roadside inspections, and quarantine treatments (Curlett, 1993). In Baja California, for example, over 1,000 traps for MFF are used to monitor its population. These suppression programs keep the insect populations low or eradicated in the pest-free zones, which provides a barrier for the U.S. growers. The Mexican growers benefit from the pest-free zones, decreased pest control expenses and less stringent quarantine provisions to ship to the U.S.[14] In 1998, however, more than 50 MFFs were trapped in the Tijuana and Ensenada area of Baja California. Between 8 to 16 million sterile MFFs were released

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[14]No estimates of the production costs savings from the pest-free zone could be found.

per week to combat this outbreak. (These sterile flies are reared in a Texas facility.) The U.S. and Mexico also cooperate to control MFF in the northeastern states of Tamaulipas and Nuevo Leon, including almost 1,000 traps. Matching funds are not mandated.

Lower Rio Grande Valley

In 1964, MFF eradication attempts were stopped and suppression activities consisting of MFF sterile fly releases became the objective in the Lower Rio Grande Valley. The MFF migrates from northern Mexico on infested fruit or on the insects flying into the Texas fruit groves. Pest populations usually do not reach detectable levels until the majority of the fruit has been harvested.[15] Once an MFF is found, the affected citrus is quarantined and the grower must follow a quarantine protocol, ship the remaining products to noncitrus producing states, or sell the remaining products to the processing market, which pays a 50 percent lower price (USDA-NASS 1999). USDA (52%), the Texas Department of Agriculture (33%) and the citrus industry (15%) share the cost of the sterile fly release program (Citrograph 1987).

Control (Eradication)

Once exotic pests are detected, control or eradication is attempted to keep the exotic pest from establishing and spreading to other U.S. production regions. Since 1975, a total of 15 eradication programs have been mounted against the Medfly in California, at a cost approaching $500 million (Coppock and Kreith, 1999). If the economic losses of establishment in the U.S. would have been $1.5 billion, the benefits of eradication have outweighed the cost of $500 million over the last 25 years.

[15]The MFF population naturally decreases during the hot summer months.

However, public opposition to these program exists that is unconnected to the cost. People are concerned about the aerial spraying of Malathion near their homes. Delays in starting the 1980-1982 eradication, in part due to California's unwillingness to spray chemical insecticides over cities, resulted in new emergency powers granted to the federal government to override state control (OTA, 1993). The eventual cost of this eradication project in the San Jose-Santa Clara area was at least $100 million. Yet the public seems unaware that the establishment of a permanent pest population will also result in increased chemical use to deal with economically destructive pests. If the city population lives sufficiently distant from the growing regions, perhaps it thinks the additional chemical use to control a permanently established pest population in agricultural fields will have less impact on it.

Other Cooperative Programs

Cooperative programs also exist to establish and maintain barrier areas such as pest-free zones and to decrease pest migration potential. One of the successful ongoing programs is MOSCAMED (Medfly in Spanish). The U.S. and Mexico combined efforts to eradicate the Medfly when it was first discovered in Mexico in 1977. The USDA built and maintained the sterile insect facilities in Mexico and in Guatemala. Mexico provided the staff personnel and the majority of the funding for the program to eradicate the fruit fly. The two countries eradicated the pest from Mexico in 1981 and established a Medfly barrier zone at the Mexican-Guatemalan border. The program administration was based on the bilateral management structure used in the U.S.-Mexican Screw Worm Eradication Program.[16] Each U.S. staff person had a Mexican counterpart. Subsidized by Mexico, Guatemala began eradication and barrier maintenance

[16]This program has eradicated screw worm from Mexico through Panama where a barrier has been created at the Isthmus of Panama. Each country's share of the funding was determined by the benefits they would derive from screw worm eradication which is a function of their livestock numbers (Nichols 2001).

activities in 1977 as well. However, due to environmental concerns, the growth of the Guatemalan organic farming sector, and the negative impacts on honeybees, in 1998 the Guatemalan government ended all chemical control activities before the eradication goal was achieved (USDA APHIS 2000). Sterile insect releases continued to be used to maintain the pest barrier.

To prevent the spread of the Medfly into Mexico, MOSCAMED did and continues to support an extensive detection network (traps and checkpoints) and to produce and to release approximately 41 billion sterile Medflies annually in Mexico and Guatemala. 250 active outbreaks of the Medfly were detected in Southern Mexico in 1998 in these traps. A U.S. Science Review Panel determined that by 2005 a self-sustaining population of Medflies would exist in the U.S. if emergency action were not taken immediately. Such a Medfly population would result in a $1.5 billion of loss to the U.S. economy (Nichols 2001).

The USDA Commodity Credit Corporation gave the MOSCAMED program $23 million over 5 years to eradicate the Medfly from Guatemala. Spinosad, a new chemical, has been successful in the first years of field tests and does not kill bees. In addition, the program used Temperature Sensitive Lethal (TSL) flies, produced in Guatemala, which provided more efficient and effective results. One Guatemala region is slated to receive pest-free zone status. This Guatemala region then will be able to trade with the U.S. under less stringent quarantine protocol measures. Monitoring and surveillance activities continue, including trapping, fruit sampling and other detection activities. Quarantine checkpoints inspect cargo and travelers from South and Central America to prevent Medflies from entering Mexico and Belize (another Medfly-free country). DNA evidence suggests that one of California's most recent Medfly outbreaks arrived from Argentina, not Guatemala; therefore officials think that the Guatemala barrier is being restored. California has also begun using the sterile fruit flies produced in Guatemala as part of a Preventive Release

Program (PRP). This California program releases sterile flies over the Los Angeles basin to mitigate the risk of a Medfly introduction. If a Medfly is found, this program allows APHIS and California to use more environmentally friendly and less expensive control activities to eradicate the pest.

Conclusions

The premise that phytosanitary regulations can protect domestic agriculture from exotic pests and from foreign producers' competition is too simplistic. Under certain conditions, these regulations may accomplish the producers' goals by excluding exotic pests and maintaining higher domestic prices. However, under other conditions, the import bans lead to lower returns (smaller and often a lower price market) for foreign producers, resulting in less control of their pest population. With a lower level of control, foreign pest populations can increase, and thus the probability of migration to the U.S. increases. The introduction of exotic pests can have devastating effects on U.S. agriculture. Economic losses are estimated to range from $350 million to $1.5 billion. These costs do not take into account environmental effects from additional pesticide applications and from the exotic pest's ecosystem impacts. The fruit and vegetable producers affected by the exotic pests may lose more from the increased pest damage than from import competition. Similarly, consumers will gain less from imports (on average, prices are unlikely to fall significantly) than they will lose from pest damage to domestic producers. Thus, if an import ban would eliminate the possibility of exotic pest migration, it might maximize domestic welfare. However, if the possibility of exotic pest migration exists even if trade in the goods is prohibited, cooperative programs to decrease pest populations and improved quarantine treatments could contribute more to welfare enhancement. In the case of the Medfly, the U.S. contributes much less to the cooperative MOSCAMED program than the projected economic losses of Medfly establishment. Mexican growers benefit from the decreased production costs and the lower cost of quarantine protocol requirements. The MFF is native to Mexico and is unlikely to be eradicated from that entire country. Joint eradication efforts on the U.S.-Mexico border, however, benefit growers close to the border and provide a barrier that decreases the probability of an MFF migration further into the U.S. In Texas, suppression activities along the border and in the Rio Grande Valley have permitted Texas citrus growers to ship to their most profitable markets for most of the season. This program benefits consumers throughout the U.S. who enjoy lower citrus prices.

For many environmental issues, distributional impacts should be discussed. Why, for example, is using chemicals in Guatemala a better pest control activity than using chemical pest control in Texas? In the case of exotic species, the question may be whether to use the chemical control activities in one region or use them in all regions. If Guatemala or Mexico decided not to eradicate the exotic pest and ceased control activities, the Medfly probably would become established in the U.S.. Once established, individual growers could use chemical control activities on an annual basis. If the population level is not suppressed through these uncoordinated activities, the pest may continue its migration north. As it moves north, overall chemical use will increase as more regions attempt to control or eradicate the insect. Research continues to find more environmentally friendly chemical and non-chemical control methods to decrease the likelihood of public outcry which has affected both Guatemala's and California's ability to conduct eradication programs.

This paper explored a situation where two countries have, for the most part, cooperated to control two economically significant insect pests. There are other examples where cooperation has been less successful. For example, the U.S. imposed an import ban on avocados from Mexico in 1914. Although the APHIS scientific staff recommended a protocol to permit some Mexican avocado imports in 1973, the import ban was not lifted until 1995 (Roberts and Orden, 1997). Krissoff, Calvin and Gray (1997) outline problems with technical barriers in world apple markets. The World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Measures may assist in providing incentives and penalties to inspire more countries to behave in a cooperative manner.

References

Baker, B.P. "Pest Control in the Public Interest: Crop Protection in California," UCLA Journal of Environmental Law and Policy, 8(1): 31-71. 1988.

Brander, J.A. and B.J. Spencer, "Export Subsidies and International Market Share Rivalry," Journal of International Economics, 18: 83-100, February 1985.

California Agriculture, "Medfly - going but not gone" California Agriculture. March/April 1999

Carey, James R., "The Mediterranean fruit fly in California: taking stock," California Agriculture 46(1): 12-17. 1992.

Carpenter, Janet, Leonard Gianessi, and Lori Lynch, "Economic Analysis of the Methyl Bromide Ban," National Center for Food and Agricultural Policy Report, February 2000.

Citrograph, "California Sets Defenses for a Trans-Pacific Invasion, but Gets a Surprise Attack from South of the Border" Citrograph. December 1983.

Citrograph, "Mexican Fruit Fly Is Persistent Foe in Eradication Effort,"Citrograph. February 1984.

Citrograph, "Fruit Fly Find Stirs Action on Mexican Citrus Imports," Citrograph. April 1986.

Citrograph, "Mexican Fruit Fly Found in Los Angeles Again,"Citrograph. May 1986.

Citrograph, "Detection System Nips New Mexican Fruit Fly Outbreak," Citrograph. May 1987.

Conrad, Klaus, "Taxes and Subsidies for Pollution-Intensive Industries as Trade Policy," Journal of Environmental Economics and Management, 25:121-135, 1993.

Coppock, Raymond H. and Marcia Kreith, eds. *Exotic Pests and Diseases: Biology, Economics, Public Policy*, Agricultural Issues Center, University of California, December 1999.

Curlett, Ed. Fact Sheet: Mexican Fruit Fly USDA Animal and Plant Health Inspection Service, May 1993, http://www.ceris.purdue.edu/napis/pests/ffmx/facts.txt.

Dahlsten, D.L., R. Garcia, and H. Lorraine, "Eradication as a Pest Management Tool: Concepts and Contexts," Eradication of Exotic Pests: Analysis with Case Histories, D. L. Dahlsten and R. Garcia, eds. Dexter, MI: Thompson-Shore Inc., 1989 p 3-15.

Danthanarayana, W., Ed. Insect Flight: Dispersal and Migration, Springer-Verlag, New York, 1986.

Dowell, Robert V. and Raymond Gill. *Exotic Invertebrates and Their Effects on California.* Division of Plant Industry, California Department of Food and Agriculture.

Dowell, Robert V., and Conrad J. Krass. *Exotic Pests pose Growing Problem for California,* California Agriculture 46(1):6-12 1992.

Ehler, L.E. and P.C. Endicott, "Effect of Malathion-Bait Sprays on Biological Control of Insect Pests of Olive, Citrus, and Walnut," Hilgardia 52(5):1-47. 1984.

Environmental Assessment Team, Report on the Environmental Assessment of Pesticide Regulatory Programs, California Department of Food and Agriculture, 1978.

Foreign Agricultural Trade of the United States (FATUS), Calendar year 1990, USDA Economic Research Service, Washington, D.C., November 1991.

Forsythe, Ken and Lori Lynch. Effects of a Free Trade Agreement on U.S. and Mexican Sanitary and Phytosanitary Regulations. USDA Economic Research Service, Agriculture Information Bulletin, No. 649, May 1992.

GAO, U.S. General Accounting Office, Agricultural Inspection: Improvement Needed to Minimize Threat of Foreign Pests and Diseases, GAO/RCED-97-102, May 1997.

Grimes, Janette, "Economic Impact of the Establishment of Mexican Fruit Fly in the United States." USDA Animal and Plant Health Inspection Service, 1992.

Krissoff, B., L. Calvin and D. Gray. "Barriers to Trade in Global Apple Markets," Fruit and Tree Nuts Situation and Outlook. FTS-280, Economic Research Service, U.S. Department of Agriculture. 1997.

Lorraine, H. The California 1980 Medfly Crisis; An Analysis of Uncertainty Management under Conditions of Non-Routine Problem Solving, University of California, Berkeley, Ph.D. dissertation, 1984.

Lynch, Lori. Agricultural Trade and Environmental Concerns: Three Essays Exploring Pest Control Regulations and Environmental Issues, Ph.D. Dissertation, University of California at Berkeley, 1996.

Malavasi, A., G. Rohwer, and D.S. Campbell, "Fruit Fly Free Areas: Strategies to Develop Them." in C.O. Calkins, W. Klassen and P. Liedo (eds). Fruit Flies and the Sterile Insect Technique. CRC Press, Boca Raton, FL. 1994.

Mangle, M. Pest Control: Operations and System Analysis in Fruit Fly Management. New York: NATA ASI Series, Springer-Verlag, 1986.

Nichols, J., USDA Animal and Plant Health Inspection Service, personal communication, 2001.

Niemelä, Pekka and William J. Mattson, "Invasion of North American forests by European phytophagous insects." BioScience 46 (Nov): 741-53, 1996.

Norrbom, A. And K. Kim, A List of the Reported Host Plants of the Specifies of Anastrepha (Diptera: Tephritidae), USDA, Animal and Plant Health Inspection Service - Plant Protection Quarantine, APHIS 81-52, September 1988.

Office of Technology Assessment, (OTA), U.S. Congress, Harmful Non-Indigenous Species in the United States, OTA-F-565 Washington, DC: U.S. Government Printing Office, September 1993.

Orden, David, and Donna Roberts, Eds., Understanding Technical Barriers to Agricultural Trade. Proceeding of the International Trade Research Consortium, January 1997.

Pedgley, D.E., "Managing migratory insect pests - a review," International Journal of Pest Management, 39(1):3-12, 1983.

Prewett, Ray, "Texas Faces Crisis on Mexican Fruit Fly Program," Citrograph, April 1987 p 113.

Roberts, Donna, "Analyzing Technical Trade Barriers in Agricultural Markets: Challenges and Priorities," Agribusiness, 15(3):335-354, 1999.

Roberts, Donna, "Prelimary Assessment of the effects of the WTO agreement on sanitary and phytosanitary trade regulations," Journal of International Economic Law, 1(3):377-405, 1998.

Roberts, Donna, Timothy E. Josling, and David Orden. A Framework for Analyzing Technical Trade Barriers in Agricultural Markets. Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Technical Bulletin No. 1876 (TB-1876). March 1999.

Roberts, Donna and David Orden. "Determinants of Technical Barriers to Trade: The Case of US Phytosanitary Restrictions on Mexican Avocados, 1972-1995," eds. David Orden and Donna Roberts, Understanding Technical Barriers to Agricultural Trade, The International Agricultural Trade Research Consortium. 1997.

Siebert, Jerome B., "Economic Analysis of the Establishment of Medfly in California," in David Zilberman and Jerome B. Siebert, Economic Perspectives on Pesticide Use in California, Department of Agricultural and Resource Economics, University of California, Berkeley, CA, October, 1990.

Siebert, Jerome B., and Todd Cooper, "Embargo on California produce would cause revenue, job loss," California Agriculture, 7-12, July-August, 1995.

Sills, Joan, USDA Animal and Plant Health Inspection Service, personal communication, 2001.

USDA APHIS, United States Department of Agriculture, Animal and Plant Health Inspection Service, Fruit Fly Cooperative Control Program Draft Environmental Impact statement – 1999. Marketing and Regulatory Programs, APHIS, 1999a.

USDA APHIS, United States Department of Agriculture, Animal and Plant Health Inspection Service, The Mediterranean Fruit Fly, Plant Protection and Quarantine, APHIS, May 1999b.

USDA APHIS, United States Department of Agriculture, Animal and Plant Health Inspection Service APHIS FY 2001 REFERENCE BOOK http://www.aphis.usda.gov/bad/refbook2001/ 2001.

USDA APHIS, United States Department of Agriculture, Animal and Plant Health Inspection Service APHIS FY 2000 REFERENCE BOOK http://www.aphis.usda.gov:80/bad/refbook2000/FruitFly.pdf 2000

USDA NASS, United States Department of Agriculture, National Agricultural Statistics Service. *Citrus Fruits, Final Estimates 1992-97.* Statistical Bulletin Number 961. August 1999.

Vo, Trang, USDA Animal and Plant Health Inspection Service, personal communication, 2001.

Vo, Trang , Economic Analysis of the Mediterranean Fruit Fly Program in Guatemala, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, August 1989.

Wilson, Charles L., and Charles L. Graham, eds. Exotic Plant Pests and North American Agriculture, Academic Press, New York, 1983.

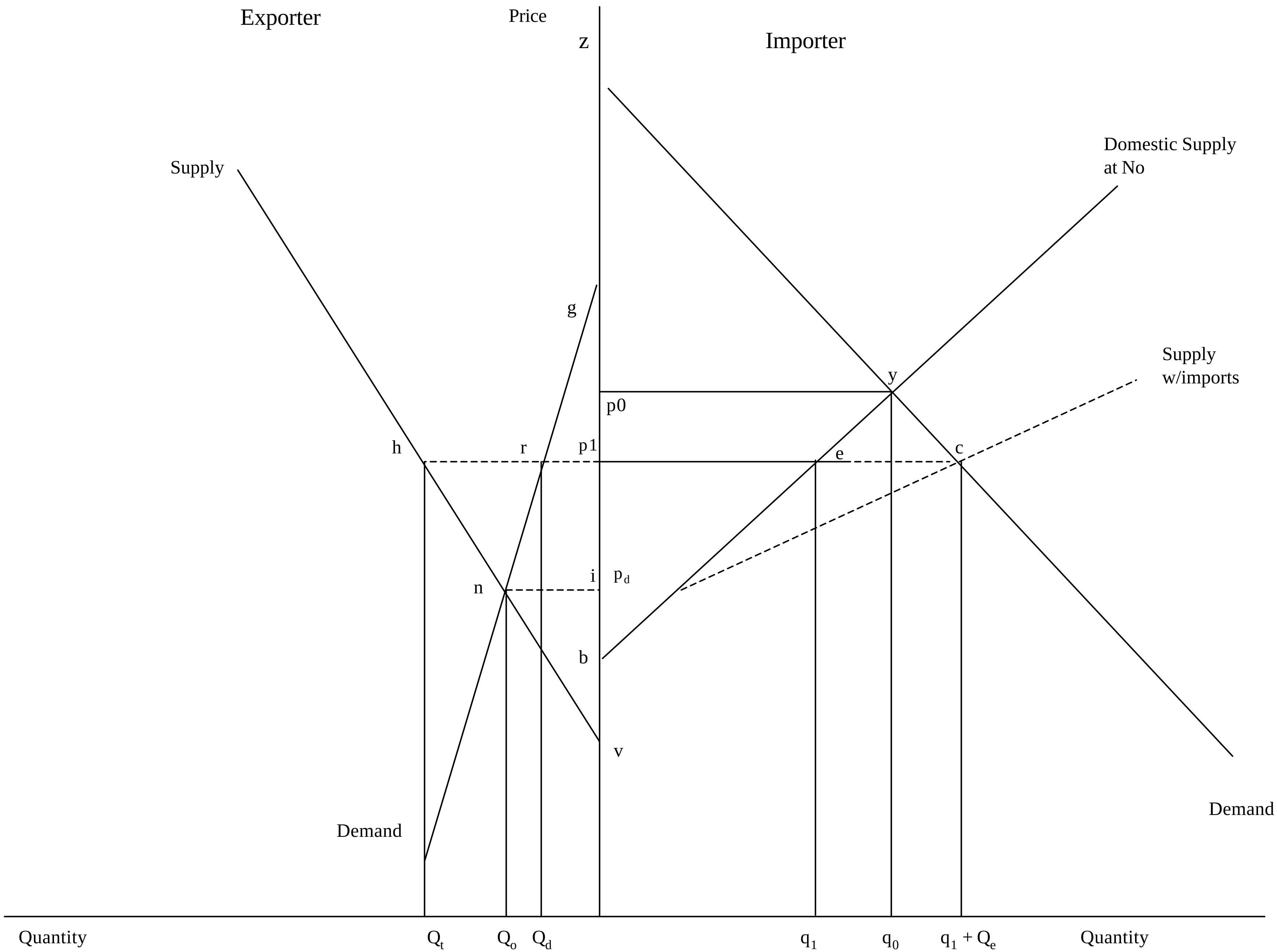

Figure 1. Domestic Welfare Changes with an Open Economy

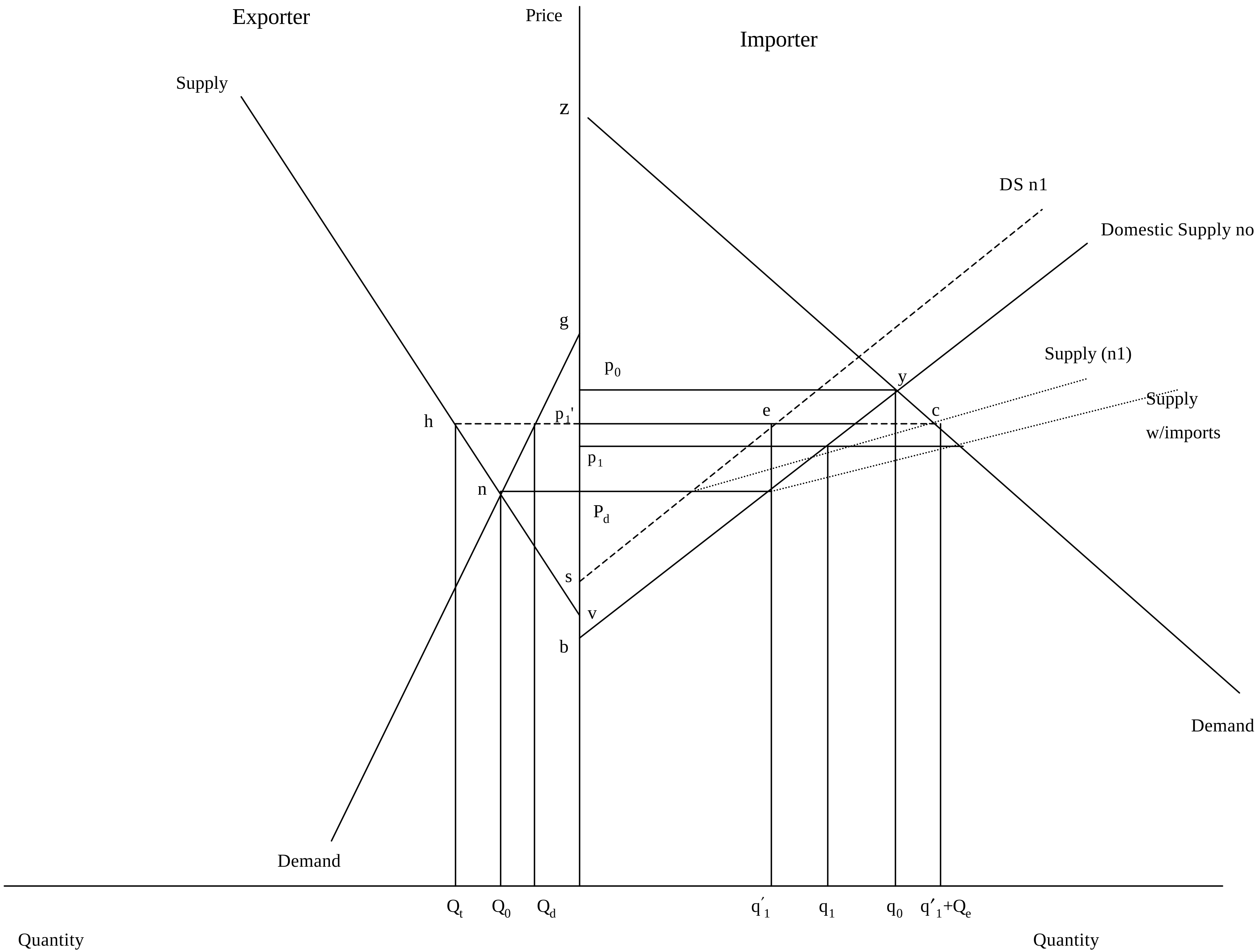

Figure 2. Exotic Pest Population Increase and Domestic Welfare Changes – Increase in Consumer Surplus

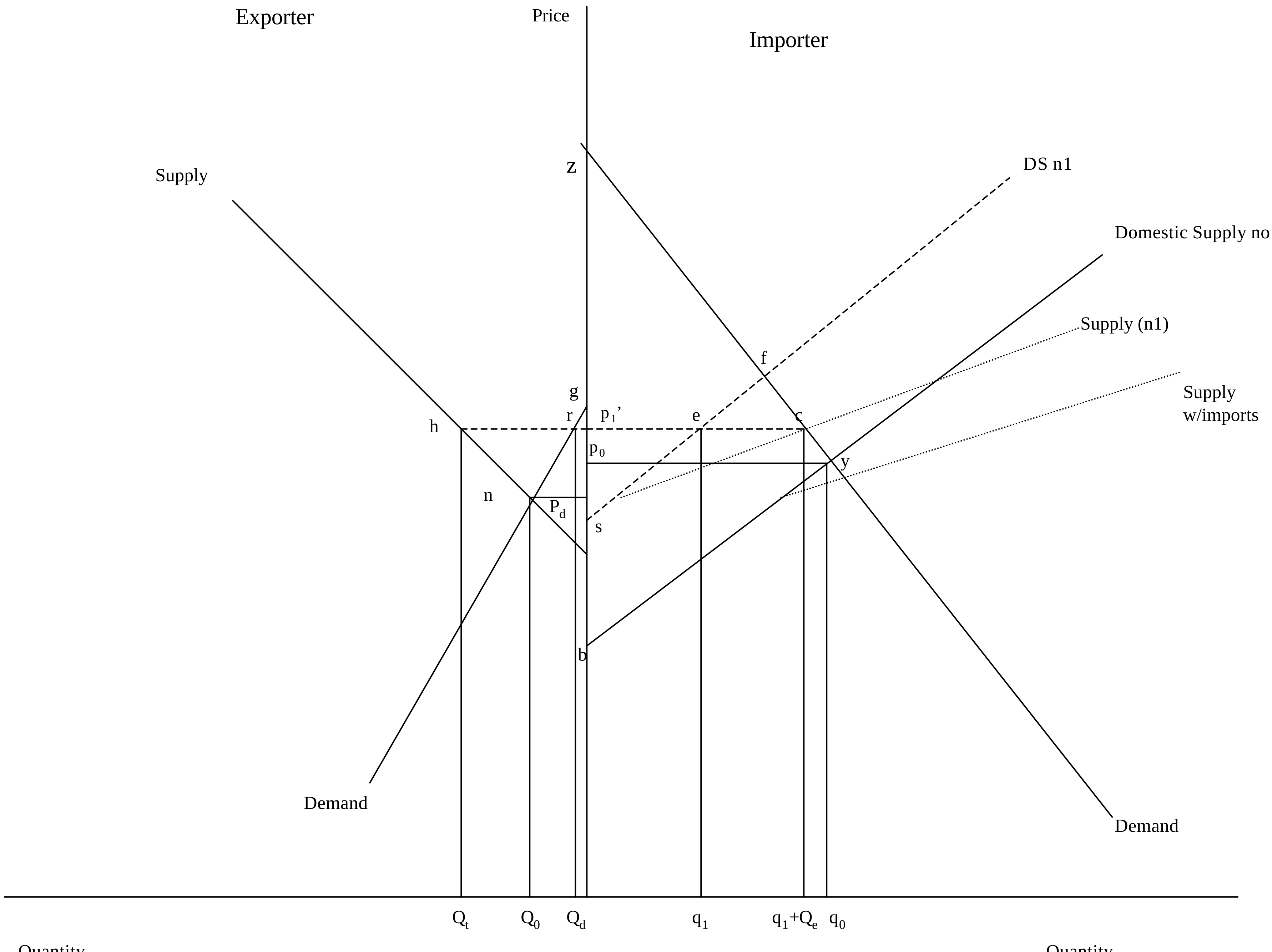

Figure 3. Exotic Pest Population Increase and Domestic Welfare Changes – Decrease in Consumer Surplus

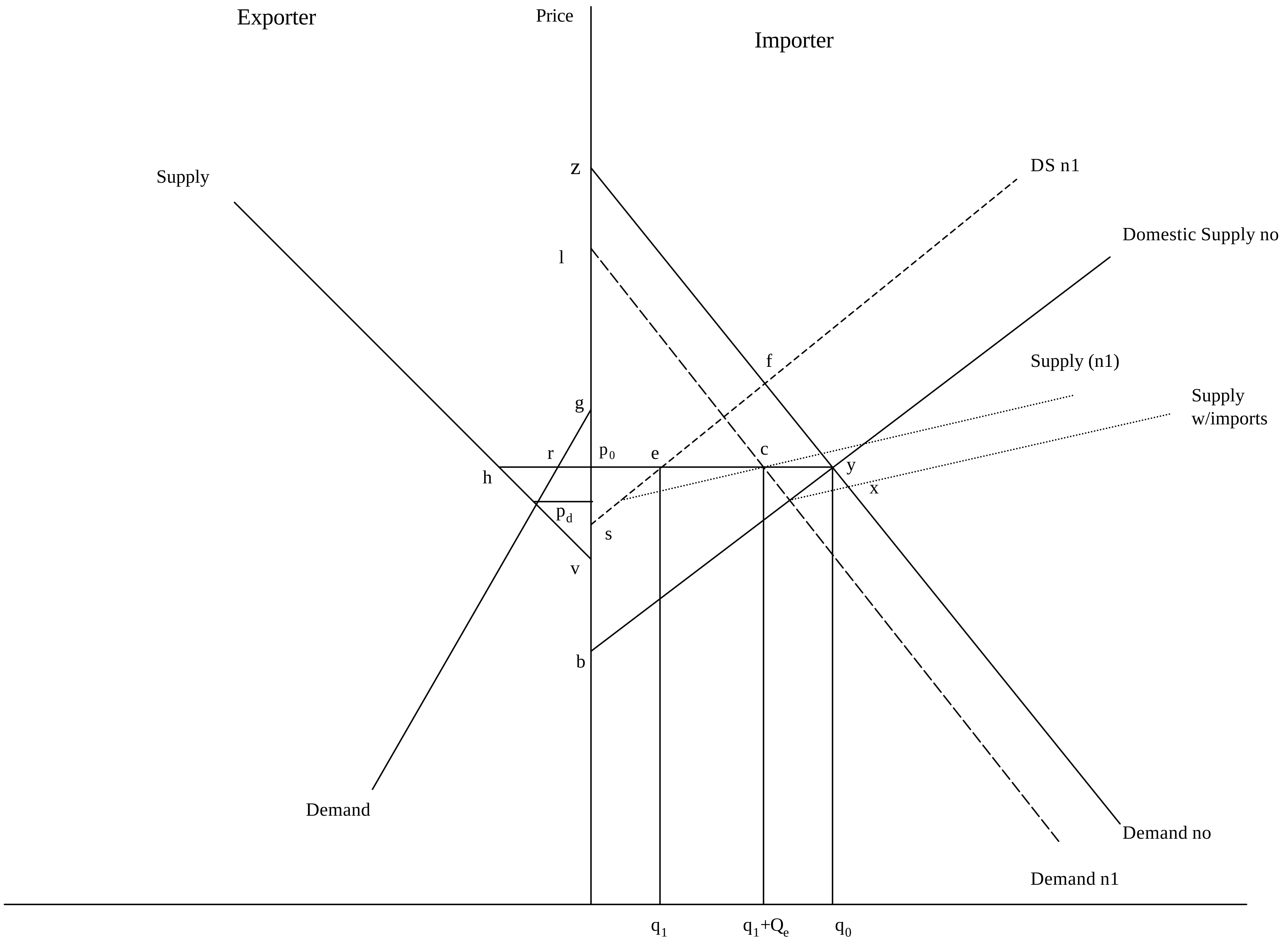

Figure 4. Exotic Pest Population Increase and Demand Contraction