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Linking Risk and Economic Assessments in the Analysis of Plant Pest Regulations

The Case of U.S. Imports of Mexican Avocados

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Abstract

This study compares the effects of importing fresh Mexican Hass avocados into the United States under three scenarios for mitigating pest risks. The analysis finds that Scenario 1, adherence to the U.S. phytosanitary rule of November 2004—which removed all seasonal and geographic restrictions on Mexican avocados, while maintaining existing compliance procedures in Mexico—leads to low pest risks for U.S. producers and an estimated annual U.S. welfare gain of $72 million. In Scenario 2, if compliance measures specific to fruit fly control are eliminated along with seasonal and geographic restrictions, pest risks for U.S. producers remain low and there is an additional gain in net U.S. welfare of $1.7 million. Results for Scenario 3, which eliminates all control measures in Mexico, depends on the level of pest-risk estimated. With average risk, there is a gain in net U.S. welfare of about $8.5 million compared with eliminating only seasonal and geographic restrictions, but U.S. producers incur significant pest control costs. With maximum pest-risk estimates, the net gain in U.S. welfare is $16.2 million less than if only geographic and seasonal restrictions are eliminated, with larger pest control costs for U.S. producers and lower consumer welfare gains due to pest-related losses of U.S. avocados.

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Introduction

Technical barriers are often significant obstacles to market access for agricultural exporters. One approach to easing technical trade restrictions is to shift from the most restrictive, such as complete bans, to less restrictive requirements for pest control. One alternative is a systems approach to risk management, whereby a set of compliance procedures is specified to reduce the pest risk from importing a commodity. These requirements add to exporter production costs, but enable market access. Systems approaches have a firm foundation in Article 5.6 of the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), which states that members shall ensure that their measures "are not more trade-restrictive than required to achieve their appropriate level of sanitary or phytosanitary protection" (WTO, 1994).

Since 1993, a long dispute between Mexico and the United States over U.S. restrictions on imports of Hass avocados has been largely resolved by replacing an import ban with trade under a system of measures designed to reduce fruit fly and avocado-specific pest risks. This case illustrates that technical trade restrictions can be eased when the risk issues can be sharply delineated and governments are firmly committed to negotiations. The easing of the longstanding import ban on Mexican avocados through a systems approach occurred in four steps:

(1) In 1993, Hass avocados from Mexico were permitted entry only into Alaska.
(2) In 1997, Hass avocados from Mexico were allowed entry into 19 Northeastern States and the District of Columbia during the months of November through February.
(3) In 2001, the area approved for import was expanded by an additional 12 States, and the import period was extended to October 15 to April 15
(4) In November 2004, all geographic and seasonal restrictions were effectively eliminated, allowing year-round importation of Mexican avocados into 47 States (excepting California, Florida, and Hawaii) starting in 2005, with access to all States after a 2-year implementation delay (USDA, 2004).

Thus, nearly 15 years after the avocado trade issue was brought to the fore during the negotiation of the North American Free Trade Agreement (NAFTA), and 11 years after the initial opening of the U.S. market, an import ban in place since 1914 was reversed. USDA's Animal and Plant Health Inspection Service (APHIS) estimates the net economic benefits to the United States of the most recent rule, compared with the 2001 rule that still limited Mexican access geographically and seasonally, are about $70 million annually (USDA/APHIS, 2004a).

The USDA/APHIS economic analysis of full opening of the U.S. market assumed no risk of pest infestation as long as the measures in Mexico remained in effect. We extend the analysis to consider pest risks, Mexican costs of compliance with the systems approach, and U.S. producers' control costs and production losses in the event of a pest infestation. We find that the expanded trade anticipated under the November 2004 rule lowers Mexican per unit compliance costs by half (from nearly 20 percent to about 10 percent of producer prices). Because pest risks are low with the compliance measures still in place, the estimated annual net U.S. welfare gain from eliminating all geographic and seasonal restrictions is approximately $72 million. Next, we consider removing some or all of the systems approach measures, with corresponding compliance cost savings but greater pest risks. If only the measures for reducing Mexican fruit fly infestations (all field trapping and post-harvest quarantine requirements in Mexico) are eliminated, compliance costs fall by another 20 percent. In that scenario, the pest risk to U.S. producers increases by two orders of magnitude (100 times), but remains low in absolute terms, and there is a slight additional net welfare gain of $1.7 million for the United States.

The outcome is less certain if the systems approach is abandoned, with all pest-risk mitigation measures against fruit flies and the targeted avocado pests eliminated. In the best case, based on the APHIS estimates of the average probabilities of a pest infestation with all control measures eliminated, there is an additional gain in net U.S. welfare of $8.5 million compared with eliminating only the seasonal and geographic restrictions. Expanded consumer benefits more than offset an additional pest-related reduction in producer surplus of $5.2 million to California producers. However, using the maximum APHIS estimates of pest risks, infestations due to imported avocados become frequent enough that California producers lose an additional $12.3 million in producer surplus and consumers receive $3.8 million less in welfare gain compared with the first scenario, that is, with year-around access to all States with all compliance measures in place in Mexico. In this worst case, the net gain in U.S. welfare is $16.2 million lower than in any other scenario considered.

Our analysis of these alternative pest-risk management policies suggests three broad conclusions:

> (1)When pest risks and related costs (Mexican cost of compliance and domestic producers' pest control costs and production losses) are incorporated in the analysis, the estimated net gain in U.S. welfare does not differ substantially from the USDA/APHIS analysis that did not include these costs.
> (2)There may be modest additional gains from further modifying of the systems approach to reduce compliance costs associated with fruit fly control measures.
> (3)When we posit a scenario that abandons the systems approach completely, our knowledge of the level of pest risk is not precise enough to rule out a smaller net gain in U.S. welfare than the gain when all or some of the systems approach compliance measures are retained. Thus, this scenario is a less conservative decision in terms of pest risk or economic criteria.

In the next section we develop a general framework for incorporating pest risk, exporter compliance costs, and domestic pest-related costs in an expectation-weighted partial equilibrium market analysis. The model includes three general supply regions: domestic supply by the importer, excess supply from an exporter free of pests, and excess supply from an exporter not free of pests. The following section implements the general framework for the avocado case. The avocado model incorporates three supply regions (Southern California, Chile, and Mexico) corresponding to the theoretical regions, substitution possibilities between two seasons (winter and summer), and four domestic (U.S.) demand regions. Pest risks and related domestic costs are derived from USDA/APHIS studies. Mexican compliance costs were investigated during field research in the avocado-exporting state of Michoacán. The report concludes with the model simulation results, contrasting the pest risks and economic outcomes under three alternative scenarios to a baseline case of restricted geographic and seasonal access prior to the November 2004 rule. The three scenarios, as summarized above, are unlimited access to the U.S. market with the Mexican compliance measures in effect as specified in the 2004 rule, further removal of the fruit fly compliance measures, and elimination of all systems approach requirements.

General Framework of the Model

To analyze the benefits and costs of alternative policies, we assume that a regulator will chose the policy (ϕ) that will maximize expected welfare (EW). Following Glauber and Narrod (2001) and Rendleman and Spinelli (1999), we define expected change in welfare as:

$$(1) \qquad EW = p(\phi)W_D(\phi) + \left[1 - p(\phi)\right]W_N(\phi) - C(\phi) - W_0,$$

where p is the probability of a disease/pest outbreak, WD is the welfare if an outbreak occurs, WN is the welfare if no outbreak occurs, C is the cost of the regulatory policy, and W0 is the welfare before the policy was implemented. Welfare is defined as the sum of consumer surplus and producer surplus.

To determine the expected changes in consumer and producer surplus, a partial equilibrium trade model is developed in which imports are linked to the possibility of introducing a plant pest or disease into the importing region (Paarlberg and Lee, 1998). The partial equilibrium model will determine the level of imports and the associated risk of a pest outbreak, as well as the expected welfare. We focus on a proposed regulatory change that eliminates an import quarantine.

For tractability, the model will focus on a pest that will affect a single product or commodity market. The model identifies three different regions: region 1 is an importer of the product, region 2 is an exporter deemed free of the pest or pathogen, and region 3 is an exporter who is not free of the pest and has some probability of transmitting the pest to the importer.

Demand in the Importing Region

Demand in the importing region is derived from a utility function for a representative consumer. To allow for possible product differentiation between regions, the model assumes that consumers view the product from each region as a similar but slightly different product. For example, consumers in the importing region may view the product from the importing region as being fresher than a product from a more distant region.[1]

In general notation, the quantity demanded of the product from region j (Q_j^D) is a function of the retail price of product j (p_j) in the importing country:

$$(2) \quad Q_1^D = D_1(p_1, p_2, p_3), \ \frac{\partial Q_1^D}{\partial p_1} \le 0, \ \frac{\partial Q_1^D}{\partial p_2} \ge 0, \text{ and } \frac{\partial Q_1^D}{\partial p_3} \ge 0\,;$$

$$(3) \quad Q_2^D = D_2(p_1, p_2, p_3), \ \frac{\partial Q_2^D}{\partial p_1} \ge 0, \ \frac{\partial Q_2^D}{\partial p_2} \le 0, \text{ and } \frac{\partial Q_2^D}{\partial p_3} \ge 0\,; \text{ and}$$

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[1] A homogeneous good model is just a special case of a differentiated goods model, in which the elasticity of substation in final demand is equal to infinity.

(4) $$Q_3^D = D_3\left(p_1, p_2, p_3\right),\ \frac{\partial Q_3^D}{\partial p_1} \geq 0,\ \frac{\partial Q_3^D}{\partial p_2} \geq 0,\ \text{and}\ \frac{\partial Q_3^D}{\partial p_3} \leq 0\,.$$

The demand curves for all goods are downward sloping and all goods are assumed to be substitutes for one another.

Supply in the Importing Region

The expected quantity supplied by producers in the importing region (Q_1^S) is assumed to be a function of the producer price, which is defined as the retail price minus a fixed marketing margin [2] (m_1), the frequency of pest outbreaks (*N*), and the costs associated with controlling any outbreak that occurs (PC_1):

(5) $$Q_1^S = S_1\left(p_1 - m_1, N, PC_1\right);\ \frac{\partial Q_1^S}{\partial\left(p_1 - m_1\right)} \geq 0;\ \frac{\partial Q_1^S}{\partial N} \leq 0;\ \frac{\partial Q_1^S}{\partial PC_1} \leq 0;\ N \geq 0;\ \text{and}\ PC_1 \geq 0\,.$$

The supply function in equation (5) identifies two potential shifts from a pest outbreak. First, an outbreak will reduce productivity, and therefore the quantity supplied. Second, some or all of the loss in productivity may be mitigated through control measures. Because the control measures may not fully eradicate the pest, there could be a decline in productivity along with an increase in production cost from a pest outbreak. This would suggest that $\partial^2 Q_1^S / \partial N \partial PC_1 \geq 0$.

Frequency of Pest Outbreaks

The frequency of pest outbreak is defined to be a function of the regulatory policy under consideration (ϕ) and the level of imports from region 3 (Q_3^E):

(6) $$N = N\left(\phi, Q_3^E\right);\ \frac{\partial N}{\partial Q_3^E} \geq 0;\ Q_3^E \geq 0;\ \text{and}\ N\left(\phi, 0\right) = 0\,.$$

The frequency of pest outbreaks increases as the level of imports from region 3 increases and is equal to zero if there are no imports from region 3.

The relationship between Q_3^E and *N* will depend on the product in question. In general, the following relationship can exist between Q_3^E and *N*. Let:

$prob1\left(\phi\right)$ = probability that the product being exported is infested,
$prob2\left(\phi\right)$ = probability that the pest survives shipment,
$prob3\left(\phi\right)$ = probability that the product/pest is transported to a suitable habitat, and

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[2] The marketing margin includes all trade and transport services needed to get the product from producers to consumers. This margin provides the link between producer and retail prices.

$prob4(\phi)$ = probability that the pest is able to become established.

Note that magnitudes of these four probabilities will depend on the regulatory policy under consideration. Assuming that all four events are required for an outbreak to occur and that each event is independent, then equation (6) is specified as:

$$N = prob1(\phi) * prob2(\phi) * prob3(\phi) * prob4(\phi) * Q_3^E .$$

Pest-Control Costs in the Importing Region

The cost of mitigation measures used by producers in the importing region to control an outbreak is assumed to be a function of the frequency of an outbreak, the intensity of an outbreak (Int_1), and the level of eradication (α):

$$(7)\quad PC_1 = PC_1\left(N, Int_1, \alpha\right);\ \frac{\partial PC_1}{\partial N} \geq 0;\ \frac{\partial PC_1}{\partial Int_1} \geq 0;\ \frac{\partial PC_1}{\partial \alpha} \geq 0;\ \text{and}\ \frac{\partial^2 PC_1}{\partial \alpha^2} > 0 .$$

As the intensity of an outbreak or the level of eradication increases, the cost of mitigation also increases. Note that the level of eradication may vary between 0, or no eradication effort and 1, full eradication. This implies that if the eradication effort is 0 or there is no outbreak, then:

$$PC_1\left(N, Int_1, 0\right) = 0 = PC_1\left(0, Int_1, \alpha\right).$$

The cost of eradication is assumed to grow at an increasing rate. While not specifically noted in equation (7), it is possible to make the second partial derivative with respect to the intensity of the outbreak to be increasing. Thus, the cost of control measures is increasing at an increasing rate.

Exporter Excess Supplies

The level of exports from region 2 (Q_2^E) is specified as an excess supply function that is increasing in the export (or f.o.b.) price of the product in region 2 (e.g., the retail price in region 1 minus a fixed margin):

$$(8)\qquad Q_2^E = E_2\left(p_2 - m_2\right);\ \frac{\partial Q_2^E}{\partial\left(p_2 - m_2\right)} \geq 0 .$$

The level of exports from region 3 is specified as an excess supply function, increasing in the export price in region 3 and decreasing in the cost of control measures (PC_3) required by the regulatory policy being considered in region 1:

$$(9)\qquad Q_3^E = E_3\left(p_3 - m_3, PC_3\right);\ \frac{\partial Q_3^E}{\partial\left(p_3 - m_3\right)} \geq 0;\ \text{and}\ \frac{\partial Q_3^E}{\partial PC_3} \leq 0 .$$

Control Costs in the Exporting Region With Pest Risk

The cost of control measures for producers in region 3 will depend on risk-mitigation practices specified in the regulatory policy under consideration:

(10) $$PC_3 = PC_3\left(\phi\right).$$

If a pest outbreak occurred, the producers in region 3 would also bear the cost of eradicating the pest. This cost is not included in the model because it is assumed that a pest outbreak would lead to reinstatement of the import quarantine. In this case, the cost of eradication would not be directly related to the risk-mitigation practices specified in the regulatory policy, and therefore it is not included in the model.

Market Clearing Conditions

The market-clearing conditions equate the demands for the substitutable products in region 1 with the supplies from regions 1, 2, and 3:

(11) $$Q_1^D = Q_1^S.$$

(12) $$Q_2^D = Q_2^E.$$

(13) $$Q_3^D = Q_3^E.$$

Equations (2) through (13) constitute the market portion of the model. The endogenous and exogenous variables of this portion of the model are:

> Endogenous: $Q_1^D, Q_2^D, Q_3^D, Q_1^S, Q_2^E, Q_3^E, p_1, p_2, p_3, N, PC_1,$ and PC_3.
> Exogenous: $\alpha, Int_1, m_1, m_2,$ and m_3.

The number of regulatory options in policy set ϕ is assumed to be exogenous.

Welfare Measures

To distinguish the optimal regulatory option, the change in expected welfare is computed for all of the policy options under consideration. The option with the largest increase in expected welfare will be the optimal policy. The change in expected welfare for the region 1 is defined as:

(14) $$EW_1 = CS_1\left(\phi\right) + PS_1\left(\phi\right) - PC_1 - PCP_1,$$

where $CS_1\left(\phi\right)$ is the expected change in consumer welfare (surplus) in region 1, $PS_1\left(\phi\right)$ is the change in producer surplus in region 1, PC_1 is the cost of control measures borne by producers in region 1, and PCP_1 is the cost of control measures paid by public agencies in region 1.

The cost of control measures paid by public agencies will consist of inspections or pest-eradication programs required by the regulatory policy but not paid for by the producers. For example, inspections at the border of the importing country are paid for by the taxpayers. The cost of inspections or other control measures will depend on the regulatory policy under consideration, the level of exports from region 3, and the intensity of infestations in regions 1 and 3:

$$(15)\quad PCP_1 = PCP_1\left(\phi, Q_3^E, Int_1, Int_3\right);\ \frac{\partial PCP_1}{\partial Q_3^E} \geq 0;\ \frac{\partial PCP_1}{\partial Int_1} \geq 0;\ \text{and}\ \frac{\partial PCP_1}{\partial Int_3} \geq 0\,.$$

The infestation intensity in each region is included because more intense outbreaks may lead to higher levels of inspection.

Consumer welfare in region 1 is defined as the equivalent variation (EV_1) due to the change in regulatory policy in region 1:

$$(16)\qquad CS_1\left(\phi\right) = EV_1\left(\phi\right) = e_1\left(p_0, u\left(\phi\right)\right) - e_1\left(p_0, u_0\right),$$

where: e = expenditure function derived from the utility function for the
representative consumer,
p_0 = initial (or current) retail prices,
u_0 = initial level of utility, and
$u\left(\phi\right)$ = level of utility after the change in regulatory policy.

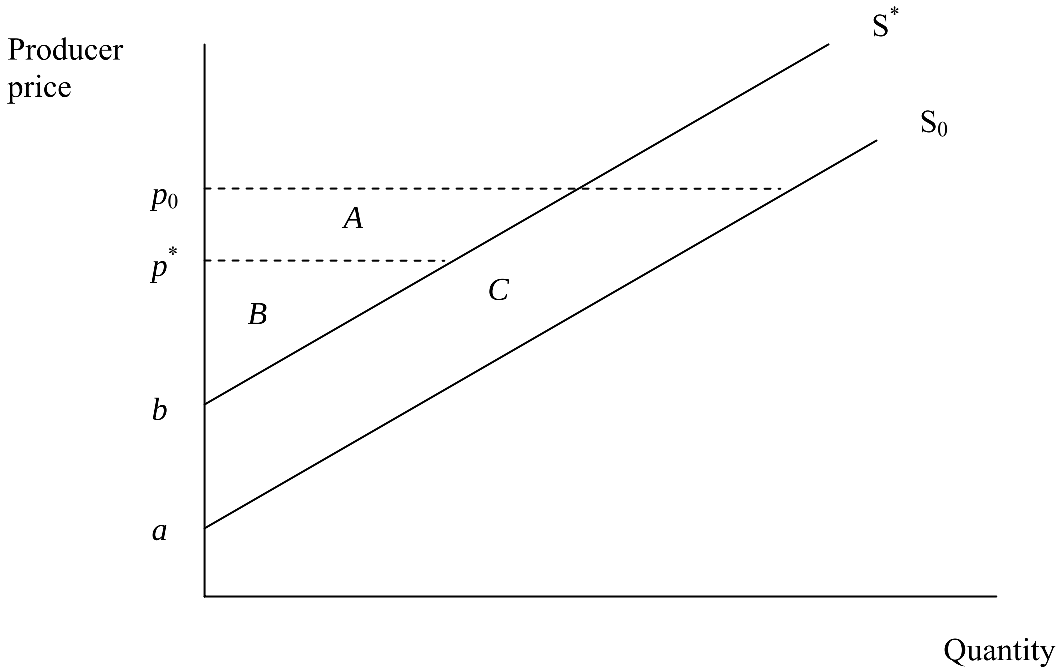
Because the supply curve will shift to the left due to productivity losses and/or the cost of pest-control measures, the change in producer surplus in region 1 is equal to the producer surplus after the change policy minus the producer surplus before the change. (fig.1). This can be expressed as:

$$(17)\quad PS_1\left(\phi\right) = \int_b^{p^*} S_1\left[p_1 - m_1, N, PC_1\right] d\left(p_1 - m_1\right) - \int_a^{p_0} S_1\left[p_1 - m_1, 0, 0\right] d\left(p_1 - m_1\right),$$

where *a* is the intercept of the supply function, p_0 is the producer price level before the policy change, *b* is the intercept of the supply function, and p^* is the producer price level after the policy change. This change is shown graphically in figure 1, where S_0 is the supply curve before the policy change, S^* is the supply curve after the policy change, and p_0 and p^* are the producer prices before and after the policy change. The level of producer surplus after the policy change is the triangle *B*. The level of producer surplus before the policy change is the sum of the areas *A*, *B*, and *C*. Thus, the loss in producer surplus is the sum of areas *A* + *C*.

Figure 1

Change in producer surplus from a shift in the supply function



Source: Authors’ depiction of pest impacts**.**

Implementing the Model for the U.S.-Mexico Case

To compare the effects of implementing the 2004 phytosanitary rule that eliminated seasonal and geographic restrictions on the importation of fresh Hass avocados from approved orchards in Mexico under three different sets of systems approach compliance measures, we use the framework developed above to construct a static, partial equilibrium model. This model is used to simulate the effects on prices, quantities, and welfare of the 2004 phytosanitary rule for each systems approach scenario.

The 2004 Phytosanitary Rule: Background

From 1914 until 1993, the entry of fresh Hass avocados from Mexico into the United States was prohibited due to phytosanitary risks. In 1993, Mexico avocados were allowed into one state (Alaska). In November 1997, Mexican avocados were allowed into the conterminous United States for the first time. Entry was allowed into 19 northeastern States and the District of Columbia from November through February, with a set of risk-mitigation measures required of approved export orchards and packers.[3] In 2001, the area approved for import was expanded by an additional 12 States, and the period of importation was extended to 6 months, October 15 to April 15.[4] The November 2004 rule allows year-round entry of fresh Hass avocados from Mexico into 47 States for a 2-year implementation period, after which entry will be allowed into all 50 States. The compliance measures required in Mexico are adjusted for the extended seasonal access. The model developed in this section draws heavily on a partial equilibrium model without pest risk, compliance or control costs, or productivity losses developed by Peterson, Evangelou, Orden, and Bakshi (2004). This earlier model was also adopted and modified by USDA/APHIS for assessment of the 2004 rule (USDA/APHIS 2004a).

Systems Approach

Prior to the 2004 rule, the systems approach contained nine steps or requirements: field surveys, trapping activities, field sanitation, host resistance, post-harvest safeguards, packinghouse inspections, port-of-arrival inspections, seasonal shipping restrictions, and geographic shipment restrictions. The new system eliminates the last two steps and modifies some of the remaining steps (table 1). A description follows of the current steps.

Field surveys: Two types of field surveys are required: municipality and orchard surveys. The Government of Mexico, along with APHIS, is required to conduct area surveys of Michoacán municipalities for stem weevils (Copturus aguacatae), three seed weevils (Heilipus lauri, Conotrachelus aguacatae and Contrachelus perseae) and seed moths (Stenoma catenifer) before those regions are certified as eligible to export fruit. Certification is dependent upon the municipalities being free of pests. The stem weevil survey must include a trap every 1 - 4 square miles. For the seed weevils and seed moth, the surveys must cover at least 300 randomly selected hectares in each municipality and include portions of commercial orchards, wild areas, and backyards. The surveys include foliage sampling, fruit cutting, and visual inspection. Foliage samples are collected by beating the lower branches of a tree over a white tarpaulin, with material falling onto the tarpaulin examined for pests. The survey must be conducted during the growing season and completed

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[3] The effective date of the final rule was March 7, 1997. The approved area included Connecticut, Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin.

[4] The effective date of the final rule was November 1, 2001. The States added were Colorado, Idaho, Iowa, Kansas, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming.

Table 1

Comparison of systems approaches for avocados imported from Mexico pre- and post-2005

Pre-2005 Systems approach	Post-2005 Systems approach
Field Surveys	*Field Surveys*
Once per year (municipalities and orchards certification, pest-free status, Michoacán only)	**Twice per year*** (municipalities and orchards certification, pest-free status, Michoacán only)
Trapping Activities	*Trapping Activities*
1 trap per 10 hectares to monitor for fruit flies	1 trap per 10 hectares to monitor for fruit flies
Field Sanitation	*Field Sanitation*
Remove fallen fruit weekly and prune dead branches	Remove fallen fruit weekly and prune dead branches
Host Resistance (Hass cultivar only)	*Host Resistance* (Hass cultivar only)
Remove fallen fruit weekly and prune dead branches	Remove fallen fruit weekly and prune dead branches
Post-Harvest Safeguards	*Post-Harvest Safeguards*
Transport to packinghouse within 3 hours of harvest in screened trucks; transport from packinghouse in refrigerated containers; identity of grower, packinghouse, and exporter must be maintained	Transport to packinghouse within 3 hours of harvest in screened trucks; transport from packinghouse in refrigerated containers; identity of grower, packinghouse, and exporter must be maintained
Packinghouse Inspection	*Packinghouse Inspection*
Stems and leaves removed from the fruit. Each fruit labeled with a sticker with registration number of the packinghouse. Inspectors in packinghouses inspect and cut 300 fruit sampled from each shipment. Each truck or container must be secured by Sanidad Vegetal before leaving packinghouse.	Stems and leaves removed from the fruit. Each fruit labeled with a sticker with registration number of the packinghouse. Inspectors in packinghouses inspect and cut 300 fruit sampled from each shipment. Each truck or container must be secured by Sanidad Vegetal before leaving packinghouse.
Port-of-Arrival Inspection	*Port-of-Arrival Inspection*
Inspectors ensure that the seals on the trucks are intact and shipment is accompanied with a phytosanitary certification. One fruit per box from 30 boxes per shipment are sampled, cut, and inspected.	Inspectors ensure that the seals on the trucks are intact and shipment is accompanied with a phytosanitary certification. One fruit per box from 30 boxes per shipment are sampled, cut, and inspected.
Geographical Shipment Restrictions	*Geographical Shipment Restrictions*
Shipments limited to 31 states plus District of Columbia	**None***
Seasonal Shipment Restrictions	*Seasonal Shipment Restrictions*
Shipping allowed only October 15 – April 15	**None***

*****Post-2005 change.
Source: USDA/APHIS, 2004a.

before the avocado harvest. The survey sampling is calibrated to detect pests if they are present in 1 percent or more of the area surveyed at a 95-percent confidence level.

APHIS is required to monitor Mexico's compliance with the municipality survey procedures, and Mexico's sanitary authority Sanidad Vegetal is required to inform APHIS of any pest infestations. If quarantine pests are found, the affected areas are eliminated from the export program and eradication programs initiated.

In addition to municipal surveys, each orchard must be certified in order to export fruit to the United States. To obtain certification, a grower must petition the Junta Local de Sanidad Vegetal (JLSV). Inspectors from the JLSV office visit the prospective orchard biweekly and conduct general pest inspections. After the JLSV inspector identifies the pest-free orchards, the Comite Estatal de Sanidad Vegetal (CESV) inspects the orchards once again and certifies that they are free from pathway pests (those that travel wilth avocados being shipped). Orchards that pass this inspection are tentatively approved to export the following season. APHIS and CESV inspectors conduct a third inspection the following year during the avocado growing season. Final approval to export is given only if the orchard passes all three inspections. In all inspections, fruit is cut and examined for pest infestation. Established orchards must continue to undergo pest surveys and must be recertified each year.

The only difference between the pre- and post-2004 rule systems approaches for field surveys is an increase from one to two surveys a year because of year-round access.

Field Trapping: McPhail traps are used continuously at a rate of one trap per 10 hectares to monitor for Mexican fruit flies (*Anastrepha ludens*, A. *serpentina*, and A. *striata*). If *Anastrepha* species are detected in traps, an additional 10 traps must be deployed in the surrounding 50 hectares. If another fruit fly is found, malathion bait spraying must be done every 7-10 days for the orchard to remain in the program.

Field Sanitation: All fallen fruit must be collected and removed each week, and all dead branches on the avocados trees must be pruned. Because fallen fruit – which is usually overripe or damaged – is more susceptible to pest infestation, removing it reduces the potential for infestation. Pruning helps prevent infestations of stem weevil. These sanitation practices are the responsibility of the grower or orchard owner. The JLSV monitors compliance, and the Sanidad Vegetal and APHIS assess the field sanitation practices during the orchard surveys.

Host Resistance: The Hass avocado has shown natural resistance to certain Anastrepha spp. found in Mexico and has been given "very poor host" status. Hass avocados are easily distinguishable from other varieties by their pebbly skin texture, characteristic shape and size, and blackish exterior when ripe. Accidental or deliberate substitution of other varieties is unlikely and can easily be detected.

Post-Harvest Safeguards: All avocados must be shipped to the packinghouse in enclosed trucks within 3 hours of harvest, with each box marked with the registration number of the orchard. At the packinghouse, the identity of the orchard must be maintained. In addition, all boxes in each shipping container from the packinghouse must be marked with the identity of the grower, the packinghouse, and the exporter, and the outside of each shipping container must be labeled with the registration number of the packing house. Finally, each shipping container (or truck) must be refrigerated to 5° to 8° C (41°–46.4° F).

Packinghouse Inspections: To keep out fruit flies, screens are required on all windows and double doors are required on all entrances of the packinghouse. Stems and leaves must be removed from the fruit before it is packed in boxes. This helps ensure that pests infesting these parts of the plant are excluded from the shipment. Each fruit must be labeled with a sticker with the registration number of the packinghouse. Inspectors in the packinghouse cut and examine fruit samples from each incoming shipment for the presence of pests. This typically involves cutting multiple thin slices completely through the fruit, including the seed. Before the truck or container leaves the packinghouse, Sanidad Vegetal secures it with a seal that will be broken if the truck or container is opened. Once sealed, the refrigerated truck or container must remain unopened until it reaches the United States. Because the seals may be broken by Mexican authorities to inspect for drugs, under the proposed modified systems approach, safeguarding containers will replace sealing as a means to prevent infestation during shipping.

Port-of-Arrival Inspections: Prior to 2005 avocados were allowed to enter the United States at designated locations: Brownsville, Hidalgo, Laredo, Eagle Pass, and El Paso, Texas. Under the 2004 rule, port of entry restrictions have been relaxed but border inspections continue. U.S. border inspectors ensure that the seals on the trucks are intact upon arrival and that the shipment is accompanied with phytosanitary certification issued by Sanidad Vegetal, verifying compliance with all provisions of the rule. At the port of first arrival the inspectors must inspect avocados from each shipment for pests. The inspectors cut and inspect one fruit per box from 30 boxes per shipment.

Model Overview

The static partial equilibrium model consists of four demand regions in the U.S.; three supply regions, California, Chile, and Mexico; and two seasons or periods. Only Hass avocados are considered because they account for approximately 85 percent of all avocados consumed in the United States. The supply regions were chosen because nearly all U.S. Hass avocado production takes place in California and over 96 percent of all Hass avocado imports are supplied by Chile and Mexico. The two periods in the model reflect the seasonal restrictions on Hass avocado imports from Mexico before the 2004 rule. Season 1 is defined as the October 15-April 15 time period when Hass avocado imports were allowed into specified States under the 2001 rule, and Season 2 is defined as the April 16-October 14 time period when Hass avocado imports from Mexico were not allowed. The following discussion refers only to fresh Hass avocados unless otherwise indicated.

Demand Regions

Four domestic demand regions are identified in the model to reflect differences in pest-risk susceptibility and per capita consumption. Region A corresponds to the 31 Northern States and the District of Columbia where imports of fresh Hass avocados were allowed by the 2001 rule. Region A is not susceptible to outbreaks of any of the pests of concern. Region D, Southern California, is identified as a separate demand region because nearly all Hass avocado production occurs within this region and it is susceptible to both avocado pests and fruit flies. Region D consists of 11 counties: Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Tulare, and Ventura. Nearly 99 percent of all avocado farms in California are located in these counties (table 2).

The remaining portion of the United States.is disaggregated into two regions: Region B, which is defined as the Southeastern United States, and Region C, which is defined as the Pacific Northwest and Southwestern United States, northern California, and Hawaii. The per capita consumption of avocados is substantially larger in Region C compared with Region B (table 3).

The U.S. area that is susceptible to fruit fly infestation consists of plant hardiness zones 8-11, which include all or portions of California, Oregon, Washington, Nevada, Arizona, New Mexico, Texas, Louisiana, Arkansas, Mississippi, Alabama, Georgia, Florida, North Carolina, South Carolina, and Hawaii (USDA/APHIS, 2004b).[5] Only a portion of Regions B and C are in plant hardiness zones 8 through 11 and are susceptible to fruit fly infestation. Table 4 shows the proportion of the population in each State in Regions B and C that is located in these zones. Because no information is available on avocado consumption in the fruit fly-susceptible areas in Regions B and C, it is assumed that consumption in these areas is proportional to the percentage of the region's population in the susceptible areas. For example, approximately 55 percent of the population in Region B lives in a fruit fly-susceptible area, so 55 percent of avocado consumption in this region will be assumed to take place in a susceptible region. Holding these proportions constant alleviates the need to disaggregate Regions B and C any further.

[5] A small portion of the State of Virginia in the Tidewater region was classified in zone 8. However, Virginia was allowed to receive fresh Hass avocados from Mexico under the 1997 and 2001 rules and is not be classified in our model as a fruit fly-susceptible region.

Table 2

Number of avocado farms in California by county

County	Number of Farms
Southern California	
Imperial	0
Kern	0
Los Angeles	90
Orange	37
Riverside	558
San Bernardino	41
San Diego	2,757
San Luis Obispo	122
Santa Barbara	393
Tulare	50
Ventura	902
Total	4,950
Other California counties	
Madera	3
Monterey	6
San Benito	5
San Joaquin	9
Santa Clara	5
Santa Cruz	32
Total	60
Percentage of avocado farms in Southern California	98.8%

Source: Table 7, Appendix D of "Importation of Avocado Fruit (*Persea americana* Mill. var. 'Hass') from Mexico: A Risk Assessment," U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), and Center for Plant Health Science and Technology (CPHST), Washington, D.C., May 24, 2004 (USDA/APHIS, 2004b).

Table 3

Hass avocado consumption by U.S. geographic region

	2001/2002[2]			2002/2003[2]					Per capita	
	Region[3]			Region			Population		consumption	
Region[1]	CA	CH	MX	CA	CH	MX	2002	2003	2002	2003
	1,000 pounds						*Thousands*		*Pounds*	
Region A	82,058	26,414	52,315	69,153	35,992	64,178	148,852	149,697	1.08	1.13
Region B	32,939	13,918	0	29,307	21,057	0	57,963	58,704	0.81	0.86
Region C	155,079	62,721	0	140,534	98,359	0	59,404	60,306	3.67	3.96
Region D	101,126	40,312	0	81,827	54,855	0	21,755	22,103	6.50	6.18
Total	371,201	143,365	52,315	320,821	210,262	64,178	287,974	290,810	1.97	2.05

[1] Region A contains the following States: CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, VA, WV, IL, IN, KY, MI, OH, WI, CO, IA, KS, MN, MO, MT, NE, ND, SD, and WY. These States also correspond to the Northeast, East Central, and West Central regions, and a portion of the Pacific region as defined by the Avocado Marketing Research and Information Center (AMRIC). All States in Region A had access to fresh Hass avocados from Mexico during the period October 15 to April 15 under the 2001 rule. Region B consists of the following States: AL, AR, FL, GA, LA, MS, NC, SC, and TN (Southeast region). Region C consists of AK, AZ, HI, NV, OR, WA, NM, OK, TX, and Northern California (Southwest region plus Pacific region, less Southern California). Region D consist of Southern California, which is defined to include the following counties: Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Tulare, and Ventura. Regions B, C, and D did not have access to fresh Hass avocados from Mexico prior to 2005.

[2] Denotes October 15 to October 14 marketing year.

[3] Region defines the source of Hass avocados. CA denotes California, CH denotes Chile, and MX denotes Mexico. Quantity of Californian Hass avocados shipped to each region is based on monthly shipment data from the Avocado Marketing Research and Information Center. Disaggregation below the regional level involved associating specific city markets to States. ID and UT: Boise and Salt Lake City; southern CA: Los Angeles and San Diego. Quantities of avocados imported from Chile and Mexico are taken from U.S. Census Bureau monthly data. Imports from Chile are allocated proportion to the shipments of Californian avocados to those regions.

Source: Consumption assumed proportional by authors to U.S. Population estimates from the US Census Bureau.

Table 4

State and regional population in fruit fly-susceptible areas

Region/State		Population (2003) Susceptible areas	Total	Proportion
Region B				
Alabama		1,848,880	4,478,896	
Arkansas		375,220	2,706,268	
Florida		16,691,701	16,691,701	
Georgia		2,777,785	8,544,005	
Louisiana		4,476,192	4,476,192	
Mississippi		1,979,141	2,866,733	
North Carolina		1,398,443	8,305,820	
South Carolina		2,526,592	4,103,770	
Tennessee		0	5,789,796	
	Total	32,073,954	57,963,181	0.553
Region C				
Alaska		0	641,482	
Arizona		5,252,197	5,441,125	
Hawaii		1,240,663	1,240,663	
New Mexico		314,404	1,852,044	
Nevada		1,560,767	2,167,455	
Oklahoma		0	3,489,700	
Oregon		3,032,988	3,520,355	
Texas		18,568,548	21,736,925	
Washington		4,731,327	6,067,060	
Northern California		13,203,817	13,246,748	
	Total	47,904,711	59,403,557	0.806
Region D				
Southern California		21,755,238	21,755,238	
	Total	21,755,238	21,755,238	1.000

Source: The list of counties that reside in plant hardiness zones 8 through 11 was obtained from USDA/APHIS (2004b). The 2003 population estimates are from the U.S. Census Bureau.

Frequency of Pest Outbreaks

Before we specify the equation for the frequency of pest outbreaks, a brief digression is in order. The final risk assessment published in November 2004 (USDA/APHIS, 2004b) for the latest rule change used a slightly different procedure than the risk management analysis and the supplemental pest-risk assessments published in May 1995 (USDA/APHIS, 1995a). The May 1995 analyses focused on the proposed systems approach to determine the probability of a pest outbreak in the United States. However, only the geographic and seasonal restrictions were changed in 2004, not the risk-mitigation steps within Mexico. The 2004 risk assessment was based on historical observations of the number of infected fruits identified during inspections and calculated the probability of an infected piece of fruit being exported. Because the purpose of this report is to examine the marginal benefits and costs of each step or combination of steps in the systems approach, focusing on the original risk assessment is more appropriate. According to APHIS, the systems approach "operates like a fail-safe system in that redundant safeguards are built into the process. That is, if one mitigating measure fails, other safeguards are in place to ensure that the risk continues to be effectively reduced and managed" (USDA/APHIS, 1995b, p. iv). Thus, the remainder of this discussion will focus on the 1995 risk assessment

Using the definitions of the frequency of a pest outbreak from in USDA/APHIS (1995a), we construct the equation:

$$N = prob1 * prob2 * prob3 * prob4 * prob5 * prob6 * Q^{E}_{mex},$$

where prob1 = probability that a pest infects fruit pre- or post-harvest,
prob2 = probability of the pest not being detected during harvest or packing,
prob3 = probability that the pest survives shipment,
prob4 = probability that the pest is not detected at port-of-entry inspection,
prob5 = probability that the product/pest is transported to a suitable habitat,
prob6 = probability that the pest is able to become established, and
Q^{E}_{mex} = quantity of avocados exported from Mexico.

In our analysis, the model will determine the quantity of exports going to regions that are susceptible to pest infestation. Thus, prob5 is not required.[6] The frequency of a pest outbreak in season i, in demand region r is defined as:

$$N_{ir} = prob1 * prob2 * prob3 * prob4 * prob6 * Q^{E}_{mex,ir} \tag{18}$$

The outbreak frequency can be evaluated for each season (1-2) and demand region (B-D for fruit flies and D only for avocado pests). Tables 5 through 8 provide estimates of the individual probabilities for the cases where no specific risk-mitigation measures are implemented and where measures identified in the systems approach are implemented for fruit flies, seed weevils, stem weevils, and seed moths. Because exact values for all probabilities are unknown, simulations will use the average and maximum values of the estimated probabilities in table 5 through 8 to determine the sensitivity of the model to alternative pest-risk probability values.

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[6] However, one can still consider a regulatory policy that bans the sale of avocados to regions with areas that are susceptible to a pest infestation.

Table 5

Estimated probabilities for fruit fly outbreak[1] with and without risk mitigation

Probability[2]	Mean	Minimum	Maximum
No pest-risk mitigation			
Pest infests fruit: pre- or post-harvest	0.00055	0.0001	0.001
Pest not detected during harvest or packing	0.0505	0.001	0.1
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.8	0.7	0.9
Infested fruit in suitable habitat leads to outbreak	0.00055	0.0001	0.001
Systems approach			
Pest infests fruit: pre- or post-harvest	2.5E-06	5.0E-08	5.0E-06
Pest not detected during harvest or packing	4.0E-03	8.0E-05	8.0E-03
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.7	0.6	0.8
Infested fruit in suitable habitat leads to outbreak	0.00055	0.0001	0.001

[1] The term fruit flies applies to the following: *Anastrepha fraterculus*, *A. ludens*, *A. serpentine*, and *A. striata*.

[2] All probabilities are assumed to have a uniform distribution.

Source: No pest-risk mitigation: Table 5, Supplemental Risk Assessment; Systems Approach: Table 2, Addendum I to Supplement Risk Assessment., USDA/APHIS (1996).

Table 6

Estimated probabilities for seed weevil outbreak[1] with and without risk mitigation

Probability[2]	Mean	Minimum	Maximum
No pest-risk mitigation			
Pest infests fruit: pre- or post-harvest	0.00055	0.0001	0.001
Pest not detected during harvest or packing	0.101	0.002	0.2
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.65	0.5	0.8
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005
Systems approach			
Pest infests fruit: pre- or post-harvest	2.8E-05	5.0E-06	5.0E-05
Pest not detected during harvest or packing	0.00808	0.00016	0.016
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.55	0.4	0.7
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005

[1] The term seed weevil refers to *Conotrachelus aguacatae*, *C. perseae*, and *Heilipus lauri*.

[2] All probabilities are assumed to have a uniform distribution.

Source: No pest-risk mitigation: Table 6, Supplemental Risk Assessment; Systems Approach: Table 3, Addendum I to Supplement Risk Assessment, USDA/APHIS (1996).

Table 7

Estimated probabilities for stem weevil outbreak[1] with and without risk mitigation

Probability[2]	Mean	Minimum	Maximum
No pest-risk mitigation			
Pest infests fruit: pre- or post-harvest	0.055	0.01	0.1
Pest not detected during harvest or packing	0.101	0.002	0.2
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.8	0.7	0.9
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005
Systems approach			
Pest infests fruit: pre- or post-harvest	0.0055	0.001	0.01
Pest not detected during harvest or packing	0.00808	0.00016	0.016
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.7	0.6	0.8
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005

[1] The term stem weevil refers to *copturus aguacatae*.

[2] All probabilities are assumed to have a uniform distribution.

Source: No pest-risk mitigation: Table 7, Supplemental Risk Assessment; Systems Approach: Table 4, Addendum I to Supplement Risk Assessment, USDA/APHIS (1996).

Table 8

Estimated probabilities for seed moth outbreak[1] with and without risk mitigation

Probability[2]	Mean	Minimum	Maximum
No pest-risk mitigation			
Pest infests fruit: pre- or post-harvest	0.00055	0.0001	0.001
Pest not detected during harvest or packing	0.0505	0.001	0.1
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.375	0.25	0.5
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005
Systems approach			
Pest infests fruit: pre- or post-harvest	2.8E-05	5.0E-06	5.0E-05
Pest not detected during harvest or packing	0.00044	0.00008	0.0008
Pest survives shipment	0.8	0.7	0.9
Pest not detected during port of entry inspection	0.325	0.2	0.45
Infested fruit in suitable habitat leads to outbreak	0.000275	0.00005	0.0005

[1] The term “seed moth” refers to *Stenoma catenifer*.

[2] All probabilities are assumed to have a uniform distribution.

Source: No pest-risk mitigation: Table 8, Supplemental Risk Assessment; Systems Approach: Table 5, Addendum I to Supplement Risk Assessment, USDA/APHIS (1996).

Supply of Californian Avocados

Because ripe avocados can be left on the tree for many months before harvesting, producers may be able to shift avocado sales between seasons as relative prices change. A Constant Elasticity of Transformation (CET) production possibilities frontier is used to capture sales shifts between seasons. The location of the production possibilities frontier in output space is determined by the level of inputs used in avocado production. In this analysis, all inputs (e.g., labor, management, and capital) are aggregated into a single input assumed to be specific to avocado production. If a pest outbreak were to occur, the production possibilities frontier would shift towards the origin. This is because a pest outbreak reduces the quantity of avocados produced from a given level of the avocado-specific factor.

With no risk of a pest outbreak, the CET revenue function is specified as:

$$R\left(p,V\right)=\left\{\delta p_1^{\beta}+\left(1-\delta\right)p_2^{\beta}\right\}^{\frac{1}{\beta}}V\ ,$$

where δ is a parameter that is chosen during the calibration process to replicate initial seasonal supplies, β is a parameter that determines the elasticity of transformation, p_1 and p_2 are producer prices in the first and second season, and V is the level of avocado-specific factor employed. If a pest outbreak were to occur, it could require producers to use costly control measures or affect the productivity of V. To incorporate both of these potential effects, the revenue function is modified to:

$$(19)\ \ R\left(p,V\right)=\left\{\delta\left(p_1-CP\right)^{\beta}+\left(1-\delta\right)\left(p_2-CP\right)^{\beta}\right\}^{\frac{1}{\beta}}\left[1-\left(N_{1D}+N_{2D}\right)PL\right]V\ ,$$

where N_{iD} = frequency of a pest outbreak in season *i* (*i* = 1,2),[7]
CP = expected per pound cost of control measures, and [8]
PL = percent reduction in productivity due to an infestation.

The expression $\left[1-\left(N_{1D}+N_{2D}\right)PL\right]$ is the expected productivity loss due to a pest infestation.

The frequency of a pest outbreak depends on the level of imports and will vary across seasons. It is assumed that the productivity loss associated with an outbreak is the same regardless of the season in which it occurs.[9] Because it is likely that PL will depend on the intensity of the outbreak, several alternative values will be considered for each simulation scenario. The expression $\left(p_i-CP\right)$ represents the expected net price received by producers after paying for any pest-control measures.

The conditional supply functions are derived by taking the derivative of equation (19) with respect to the producer price. This yields the following expressions:

[7] Because the demand Region D corresponds to the California supply region, the frequency of pest outbreaks refers to the frequency for Region D.

[8] Because estimates for some control measures, such as the cost of controlling fruit flies, are available only on an annual basis, we allocate annual control costs on a production-quantity-share basis. This implies that the cost of control will be equal in both seasons.

[9] While an outbreak that occurs in the second season would not be expected to affect production in the preceding period, it may affect production in the first season of the following year. Given the static nature of the model, the only way to account for this possibility is to allow an outbreak in the second season to affect production in the first season.

(20) $y_1 = \delta\left(p_1 - CP\right)^{\beta-1}\left\{\delta\left(p_1 - CP\right)^{\beta} + \left(1-\delta\right)\left(p_2 - CP\right)^{\beta}\right\}^{\frac{1}{\beta}-1}\left[1-\left(N_{1D}+N_{2D}\right)PL\right]V$ and

(21) $y_2 = \left(1-\delta\right)\left(p_2 - CP\right)^{\beta-1}\left\{\delta\left(p_1 - CP\right)^{\beta} + \left(1-\delta\right)\left(p_2 - CP\right)^{\beta}\right\}^{\frac{1}{\beta}-1}\left[1-\left(N_{1D}+N_{2D}\right)PL\right]V$,

where y_i is quantity of avocados supplied in season *i*. As the risk of an outbreak increases (i.e., N_1 or N_2 increases), the expected reduction in productivity affects each season proportionally.

The supply functions in equations (20) and (21) are conditional on the level of the avocado-specific factor, which determines the location of the CET production possibilities frontier in output space. An increase in the net price received by California avocado growers ($p_i - CP$) would be expected to lead to an increase in the amount of the avocado-specific factor used as growers seek to increase the supply of avocados. The opposite would be expected if the net producer price decreased. Formally, this relationship is specified as:

(22) $V = c + d\left\{\delta\left(p_1 - CP\right)^{\beta} + \left(1-\delta\right)\left(p_2 - CP\right)^{\beta}\right\}^{\frac{1}{\beta}}$,

where the term in {} is the CET price index from the revenue function in equation (19). The impact of a pest outbreak is to lower the expected net price received by producers due to higher costs of control, thereby lowering the expected price index, leading to a reduction in avocado- specific factor utilization.

Costs of U.S. Control Measures and Pest Damage in California Avocado Orchards

Avocado producers in California face potential infestation from fruit flies and avocado-specific stem weevils, seed weevils, and seed moths. Table 9 provides a summary of all variables in the model associated with the U.S. costs of controlling a pest infestation and the productivity losses due to pest damage. The cost of control for fruit flies is based on the existing regulatory control program, the Texas Valley Mexican Fruit Fly Protocol, and on alternative control options in Texas, California, and Florida evaluated by USDA/APHIS (2000). The Texas Valley control program monitors and suppresses Mexican fruit fly populations through trapping and the release of sterile flies. It also requires all fruit from infested areas in the Lower Rio Grande Valley moving to or through other citrus-producing States to be treated. The estimated cost of responding to 12-15 detections and 3 infestations under this program ranges from \$316,000 to \$500,000 per year.

Costs of an alternative program in California of eradication, monitoring, and emergency response to detections and outbreaks is estimated to be \$150,000 per detection and \$220,000 - \$500,000 per outbreak. In order to be conservative, maximum annual cost of \$500,000 per outbreak is assumed in our model. [10] The

[10] The costs per outbreak do not include annual basic monitoring costs, since it is assumed that monitoring would be undertaken in any case. The costs of allowing widespread uncontrolled infestation of Mexican fruit flies are too large for nonmonintoring to be a policy option (see USDA/APHIS, 2000).

Table 9

Model variables associated with U.S. costs of pest control and productivity losses due to infestations

Variable	Description	Mean	Minimum	Maximum
Domestic producers				
CP_{ff}	Control cost for fruit flies per infestation	\$500,000		
Z	Cost per acre of avocado pest control	\$2,321.75		
Yield	Average yield per acre (pounds)	6,548	5,893	7,203
PL	Productivity loss from avocado pest other than fruit flies (percentage)	20%	10%	30%
Pcteff	Percentage of total production affected by infestation	3%	1%	5%

Source: USDA/APHIS (1993) and USDA/APHIS (2000).

expected annual cost of controlling fruit flies per pound of avocados may be expressed as:

$$CP_{ff} = \frac{500,000\left(N_{1D} + N_{2D}\right)}{y_1 + y_2}. \tag{23}$$

California avocado producers are assumed to pay all costs of a fruit fly outbreak in demand Region D.

Under the Texas program, fruit originating from infected areas may be treated with a variety of methods, such as fumigation with methyl bromide, cold treatment, high temperature forced air, or field application of malathion bait spray. Once treated, the fruit may be shipped to any destination. Thus, this protocol implies a zero productivity loss. We also assume a zero productivity loss from fruit flies for California avocado growers.

The potential cost of an infestation of an avocado-specific pest, such as a stem or seed weevil, is based on work by Evangelou et al. (USDA/APHIS, 1993).[11] They estimated that the pesticide and labor costs required to control a weevil or other avocado pest infestation were \$2,321.75 per acre. In addition, an avocado-specific pest infestation would result in a 20-percent per acre reduction in fruit production on all treated acres. The control cost per pound may be expressed as:

[11] The November 2004 USDA/APHIS pest risk analysis provides only qualitative assessments of the economic impacts of each type of pest infestation.

$$\text{cost/pound} = \frac{Z}{yield\left(1-PL\right)},$$

where Z is the cost per acre, yield is pounds of avocados produced per acre, and PL is the percentage productivity loss per acre from an infestation. Using the average annual yield of 6,548 pounds of avocados per acre in California for the 10-year period of the 1993/94 - 2003/04 marketing years, and assuming a 20-percent productivity loss, the average cost of control is $0.443 per pound.

Because an infestation will not likely affect all avocado orchards in California, the cost of controlling a weevil or other avocado pest infestation will depend on the amount of acreage affected. Given the uncertainty of the total acreage that would be affected, and consistent with the localized control measures used in Mexico when a pest is detected, we follow USDA/APHIS (2000) and consider infestation rates ranging from 1 to 5 percent, with a mean of 3 percent. Uncertainty about yields also affects the per pound cost of control for avocado-specific pests,
and we consider yields ranging from 5,893 to 7,203 pounds per acre. The expected per pound cost of control for avocado-specific pests in period *i* (CP_{ap}^{i}) is equal to cost per pound times the percentage of total production affected by an infestation (*pcteff*) times the frequency of an infestation (N_i) times the amount produced (y_i):

(24) $$CP_{ap}^{i} = \frac{Z * pcteff * N_{iD} * y_i}{yield\left(1-PL\right)}.$$

The expected annual average per unit cost of control for avocado-specific pests (CP_{ap}) is the summation of equation over the two seasons. On a per pound basis, this is:

(25) $$CP_{ap} = \frac{Z * pcteff}{yield\left(1-PL\right)} \frac{\left(N_{1D}y_1 + N_{2D}y_2\right)}{\left(y_1 + y_2\right)}.$$

Although these costs are borne by public pest-control agencies, in our model we assume that they are reflected in prices received by avocado producers.

Cost of Control Measures in Other U.S. Regions

Because portions of demand Regions B and C are susceptible to fruit fly infestation, the costs of controlling fruit fly infestation in these regions are also included in the analysis. The estimated cost of $500,000 per outbreak is used for controlling a fruit fly infestation in Regions B and C.

Costs of Compliance for Mexican Growers

Access to the U.S. market has substantial advantages for approved Mexican producers, but it does not come without additional costs. Estimates of the costs of compliance for Mexican avocado growers and packers were obtained during a field visit by David Orden, co-author of this report, to Uruapan, Mexico and surrounding areas in Michoacán during May 2-6, 2005. [12] He held discussions with growers and

[12] For more details, see Orden and Peterson (2005). We are indebted to Ron Campbell and Dale McNiel, Carlos Illsley, Alberto Cisneros, and other growers, packers and U.S. and Mexican sanitary inspection personnel in and around Urupan, Michoacan, for their gracious assistance with our field investigation.

packers in visits to seven packing houses and several orchards, representatives of the Michoacán Avocado Exporter, Packers, and Growers Association (APEAM), representatives of the Uruapan field office of APHIS, representatives of local and state offices of Mexico's Sanidad Vegetal (SAGARPA), packing house inspectors, and visiting representatives of the California Avocado Commission (CAC).

There are currently about 2,200 avocado orchards approved to export to the U.S. in 9 of the 21 municipalities of Michoacán. These orchards included about 27,390 hectares in 2005. As of late April 2005, about 62.6 million tons of avocados had been picked for export processing during 2004/05, or an average of 2.29 tons per hectare. Overall, there are 77,260 hectares of orchards in Michoacán, with average total production per hectare of 9.7 tons.

Orchards incur three types of costs for participating in the U.S. program: increased costs of production for approved acreage, fees paid to the local Junta de Sanidad Vegetal for avocado pest surveys and fruit fly trapping to establish and maintain certification to participate, and loss of fruit cut during the inspections. Estimates of these costs and related model parameters are shown in tables 10 and 11.

Production Costs: The U.S. export program requires field sanitation and pruning beyond levels normally undertaken by growers. In addition, only certain pest-control chemicals (e.g., pesticides) are authorized for use in the approved orchards. The increased production costs involved in participating in the U.S. program varies among orchards, depending on the management practices they already follow. Informal verbal estimates from growers of the additional cost of participating in the U.S. program ranged from "one-third higher" to "only a few (U.S.) cents per kilogram." In part, the verbal answers differed depending on whether the respondent was considering the cost per pound exported or produced in total per hectare.

Average variable costs of production for a hectare of avocados, and more detailed estimates of the increased costs for participation in the U.S. program obtained in the interviews, are shown in table 10. The MX$729 (peso) increase in the average variable cost per hectare for labor reflects increased field sanitation requirements under the systems approach.[13] Based on an approximate exchange rate of MX$10 per US$, this converts to an increase of $72.90 per hectare (table 11). The one-third increase in phytosanitary control costs (table 10) reflects the additional cost of the pesticides approved for use in orchards that export to the United States. Because the restrictions on pesticide use are not formally a part of the systems approach, they are not considered a part of the cost of compliance for Mexican avocado growers.

Sanidad Vegetal Pest Survey Costs: Growers in the U.S. program pay fees to their local Junta de Sanidad Vegetal to cover costs of avocado pest and fruit fly surveillance. Direct estimates of the costs of Sanidad inspections include $26,000 for fruit fly traps, $158,147 for fruit fly trap chemicals, and $1,283,772 for technician labor for the fruit fly trapping program and avocado-specific pest controls combined. Additional labor costs are estimated at $632,306 for other pest-control and extension activities related to the avocado program. The total survey cost of $2,100,225 is about $76.67 per hectare, based on 27,390 approved hectares.

Under the 2004 rule, field pest surveys increase from one to two per year. Assuming that the direct costs for fruit fly and avocado-specific pest monitoring double from

[13] U.S. dollars are denoted as "US$" or simply "$," while Mexican pesos are denoted as pesos or "MX$."

Table 10

Average production costs for avocados in Mexico

Item	Cost/ha (Pesos)	Additional cost for U.S. program
Cultivation Labor	2,143	2,872 (1/3 increase)
Fertilizer	10,059	10,059
Phytosanitary control	6,580	8,817 (1/3 increase)
Machinery and Equipment	17,661	17,661
Other	2,891	2,891
Administrative (5 %)	1,967	1,967
Financing	3,779	3,779
Total	45,080	48,461

Source: Costs/ha provided in "El Aguacatero," Marzo-Abril de 2005. Additional costs for U.S. program provided to authors during May 2005 interviews (Orden and Peterson, 2005).

Table 11

Model variables associated with costs of compliance by Mexican growers and packers

Variable	Description	Mean
Mexican producers		
fieldc	Cost per hectare of field sanitation	$72.90
pestsurv	Cost per hectare of JSLV pest surveys	$130.27
Ha	Hectares in approved orchards	27,390
gfruit	Proportion of total exports cut and inspected in field	0.02
Mexican shippers		
pinvest	Cost per pound packinghouse investment	$0.005
paphisv	Variable cost per pound of APHIS inspection	$0.009
paphisf	Fixed cost of APHIS inspections	$335,940
inspect	Cost of SAGARPA inspectors per plant	$12,000
Plants	Number of approved packing plants	22
pfruit	Proportion of total exports cut and inspected in packing plants	0.004

Source: Personal interviews in May 2005 (Orden and Peterson, 2005).

$1,467,919 to $2,935,838, the total cost of pest surveys will increase to $3,568,144, or $130.27 per hectare.
Loss of Fruit to Inspections: Another cost to growers and packers is the loss of saleable fruit picked from trees for inspection or sampled during packing or at border inspections. Table 12 provides APEAM estimates of the quantity and total cost of the fruit inspected. The cost of inspected fruit quadrupled between the 2000/01 and 2004/05 marketing years from $358,000 to $1,400,000 as exports expanded. Table 13 provides estimates of the pounds of fruit inspected as a proportion of the total pounds of avocados exported to the United States. Assuming an average weight of one-half pound per avocado (based on a standard 26 pound box of 48 avocados), approximately 2 percent of the total quantity of avocados exported to the U.S. is cut in the field and inspected for pests. Approximately 0.4 percent of total exports are inspected in the packing sheds and another 0.04 percent is inspected at the border.

Model Formulation of Grower Compliance Costs: The per pound cost of compliance for Mexican avocado growers (GCOST) for the systems approach to manage fruit fly and avocado-specific pest infestation is formulated in the model as:

$$(26) \qquad GCOST = \frac{\left[fieldc + pestsurv \right] ha + gfruit\left(p_1 y_1 + p_2 y_2 \right)}{y_1 + y_2},$$

where $GCOST$ = per pound cost of compliance for Mexican avocado growers,
$fieldc$ = cost per hectare of field sanitation,
$pestsurv$ = cost per hectare of JSLV pest surveys,
ha = number of hectares in approved orchards,
$gfruit$ = proportion of total exports cut and inspected in field,
p_i = producer price of avocados in Mexico in season i, and
y_i = quantity of exports of avocados from Mexico to the U.S. in season i.

We hold the number of hectares in approved orchards constant. Field sanitation and pest surveys must be performed on all hectares regardless of the quantity of avocados exported, representing a fixed cost to Mexican avocado growers. The cost of fruit inspected and cut in the field is equal to the proportion of fruit inspected times the quantity exported times the producer price of avocados. Since price and quantity exported may vary between seasons, the total cost of inspected fruit will also vary. Finally, the per pound grower cost of compliance is computed as the cost divided by the pounds of avocados exported to the United States.

Supply of Mexican Avocados

The per pound cost of compliance reduces the net price received by Mexican avocado growers. An increase in the cost of compliance will reduce the quantity of avocados exported to the U.S., all else constant. Similar to the model representation of the supply of avocados from California, the export supply of avocados from Mexico to the United States is represented using a CET revenue function and linear supply function for the level of the aggregate avocado-specific factor used. The export revenue function for Mexican avocado growers is specified as:

Table 12

Number of avocados inspected in the field, at packinghouses, and at the border

Year	Number of fruit cut (thousand)						Value
	In the field for			Packing	Border	Total	(Million US$)
	JLSV	USDA	Total				
2000/01	651.5	558.3	1,209.8	171.0	17.3	1,398.1	0.358
2001/02	937.8	678.6	1,616.4	347.5	41.2	2,005.5	0.457
2002/03	1,795.6	954.3	2,749.9	545.6	50.5	3,345.0	0.799
2003/04	1,785.0	1,275.7	3,060.8	816.4	71.3	3,948.5	1.047
2004/05	2,325.5	1,728.5	4,054.0	1,104.6	87.6	5,246.2	1.407

Source: Interviews with Michoacán Avocado Exporter, Packers and Growers Association (APEAM), May 2005 (Orden and Peterson, 2005).

Table 13

Avocados inspected as a percentage of total exports

Year	Field	Packing	Border	Total
2000/01	0.024	0.0034	0.00034	0.028
2001/02	0.015	0.0033	0.00039	0.019
2002/03	0.021	0.0042	0.00039	0.026
2003/04	0.016	0.0043	0.00038	0.021
Average	0.019	0.0038	0.00037	0.023

Note: The quantity of fruit cut is obtained from the estimates in Table 12. Each avocado is assumed to weigh approximately one-half pound, based on a 25-pound box that contains 48 avocados.
Source: Total exports for the October – September marketing year are obtained from Foreign Trade Statistics, U.S. Census Bureau, Department of Commerce.

$$(27) \qquad R(p,V)=\left\{\delta\left(p_1-GCOST\right)^{\beta}+(1-\delta)\left(p_2-GCOST\right)^{\beta}\right\}^{\frac{1}{\beta}}V\,.$$ [14]

Because no information is available on how the use or nonuse of the grower-compliance measures affects the pest infestation level in Mexico, the infestation level is assumed to be constant. Thus, the expected productivity of the avocado-specific factor in Mexico remains constant, and no adjustment to V is required in equation (27). The conditional export supply functions for seasons 1 and 2 are:

$$(28) \quad y_1=\delta\left(p_1-GCOST\right)^{\beta-1}\left\{\delta\left(p_1-GCOST\right)^{\beta}+(1-\delta)\left(p_2-GCOST\right)^{\beta}\right\}^{\frac{1}{\beta}-1}V \text{ and}$$

$$(29) \quad y_2=(1-\delta)\left(p_2-GCOST\right)^{\beta-1}\left\{\delta\left(p_1-GCOST\right)^{\beta}+(1-\delta)\left(p_2-GCOST\right)^{\beta}\right\}^{\frac{1}{\beta}-1}V.$$

The supply function for the aggregate avocado-specific factor is specified as:

$$(30) \qquad V=c+d\left\{\delta\left(p_1-GCOST\right)^{\beta}+(1-\delta)\left(p_2-GCOST\right)^{\beta}\right\}^{\frac{1}{\beta}}.$$

Costs of Compliance for Mexican Avocado Packers/Exporters

There are currently 21 packinghouses approved to export avocados to the United States under the systems approach requirements. About 300 packing operations ship avocados from Michoacán to domestic markets or export destinations (such as Japan, Canada, and Europe) that do not require the U.S. systems approach measures. These packing operations vary from open sheds where sorting into weight grades is undertaken by hand and there are no cold storage facilities to modern enclosed facilities with machine sorting and refrigeration.

Packers/exporters incur four types of costs for participation in the U.S. export program: (1) investments to establish fruit fly quarantine conditions at their plants; (2) operating costs of certification and fruit fly protection during picking and processing; (3) costs for SAGARPA inspectors to cut fruit and undertake other quarantine activities; and (4) fees to APEAM to reimburse APHIS for its inspection costs and for an avocado promotion program. The model parameters associated with these costs are shown in table 11.

Plant Quarantine Requirements: The systems approach requires that packing plants maintain enclosed quarantine conditions so that fruit flies cannot enter the area where fruit is processed and stored. Costs of upgrading a facility vary, depending on the initial structure. For less formal packing operations, these costs can be substantial, but for modern facilities the costs are relatively modest.

For example, for a medium-sized, relatively modern plant currently shipping only to the domestic market, but already equipped with machine sorting and cold storage facilities, the estimated cost of upgrading to meet USDA requirements is around $50,000. Upon approval, the plant owner can anticipate shipping about 50 containers (refrigerated truck loads) per year, about half to the domestic market and half to the

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[14] Note that the parameters δ and β in equation will differ than those in equation. The same symbols are used in order to reduce the amount of notation.

United States. Since each container carries 40,000 pounds, total shipments to the U.S. would equal 1 million pounds. Assuming the upgraded facilities would depreciate over 10 years, the projected cost for avocados shipped to the United States (without discounting) would be around \$0.005/lb (one-half cent).

An additional cost to the packing firm is the fee to become a member of APEAM. In 2004, each newly approved packing shed paid a fee of \$150,000 for membership. These fees, which are based on the value of APEAM assets and have risen from \$35,000, are not included in our model.

Costs of Fruit Fly Protection and Certification: Packers usually purchase fruit on the trees and are responsible for picking it and delivering it to the packing sheds. The systems approach requires certification that the fruit comes from approved orchards, protection from fruit flies with netting from harvest to delivery, and delivery to the packing shed within 3 hours of picking. These requirements do not raise the cost of the packing operations much beyond the inspection reimbursement costs.
Under the systems approach, inspectors from SAGARPA and APHIS must be present at the plant from arrival of the fruit from the field to its loading into sealed containers for shipment to the United States. The cost to the packing firms for the SAGARPA inspectors is collected by Sanidad Vegetal and runs about \$12,000 per year per plant.

The APHIS inspection costs budgeted for the avocado program (under the 2004 rule) for Fiscal Year 2005 (October 1, 2004-September 30, 2005) totaled \$1,275,201. This amount includes fixed costs for permanent staff in Uruapan (\$280,788) and for expenses of the APHIS Guadalajara office (\$55,152), and variable costs for field inspection staff (\$939,261). Based on exports of 104.24 million pounds of avocados between October 16, 2004 and April 23, 2005, the variable cost of field inspection staff is estimated at \$0.009 per pound.

The increase in inspection costs for year-round access to the U.S. market was undetermined at the time of our field research and will depend on the intensity of the inspection effort. In our analysis, we assume that the inspection intensity will remain constant, implying that the variable cost will remain at \$0.009 per pound. However, one initial estimate is that the variable cost of the field inspection staff will increase by around 40 percent to \$1.3 million. If annual exports increase by more than 40 percent compared with exports during October 16, 2004 –April 23, 2005, then the per pound variable cost of APHIS inspection will decline.

Model Formulation of Packer/Exporter Compliance Costs: The per pound cost of compliance for Mexican avocado packers/exporters (PCOST) is specified as:

$$(31)\quad PCOST = pinvest + paphisv + \frac{inspect * plants + paphisf + pfruit * \left(p_1 y_1 + p_2 y_2\right)}{y_1 + y_2},$$

where *pinvest* = cost per pound of packing plant investment,
paphisv = variable cost portion of APHIS inspection costs,
paphisf = fixed cost portion of APHIS inspection costs,
inspect = cost of SAGARPA inspectors per plant,
plants = number of packing plants, and
pfruit = proportion of total exports cut and inspected in packing plants.

The cost of compliance for Mexican packers is assumed to be part of the marketing margin for Mexican avocados sold in the United States. In our analysis, the number of packing plants is held constant. Because the per pound cost of compliance will vary with the level of exports, it is necessary to identify this portion of the marketing margin separately. The wholesale price (wp) for Mexican avocados in a given region in the U.S. can be expressed as:

$$wp = p + m + PCOST \,, \tag{32}$$

where p is the Mexican producer price and m is the remaining component of the marketing margin, which is held constant in the model.

Other Packer/Exporter Costs of Exporting to the United States: In addition to the costs to growers and packers, there are two additional costs of exporting avocados to the United States: (1) border inspections (information on this cost was not collected, but it is small given the limited number of fruits inspected at the border, which are bagged separately at the packing plants) and (2) an avocado promotion fee of \$0.026/lb required for the past 2 years under U.S. law for all avocados sold in the United States. For avocados from Mexico, this fee is used for promotional activities and is administered by the Mexican Hass Avocado Importers Association (MHAIA). Neither of these costs is included in the model.

U.S. Consumer Demand

The U.S. demand for avocados is derived from a weakly separable utility function for a representative consumer.[15] The utility function is assumed to partition all goods purchased by consumers into avocados and everything else. In addition, avocados produced in each of the supply regions are assumed to be heterogeneous products. This assumption rests on observed wholesale price differentials in the United States.

Figure 2 shows the assumed preference structure for a representative consumer. There are two different substitution possibilities in consumption. The parameter σ_2 represents the elasticity of substitution between avocados from the different supply regions. An increase in the price of California avocados, for example, relative to the price of avocados from Mexico and Chile will lead the representative consumer to substitute the less expensive imports for the more expensive California product.[16] The parameter σ_1 represents the elasticity of substitution between avocados from all supply regions and all other goods. An overall decrease in the relative price of avocados (represented by a price index) would lead the representative consumer to increase consumption of avocados from all regions.[17] Thus, the value of the parameter σ_1 will determine the magnitude of the aggregate own-price elasticity of demand for avocados in the model.

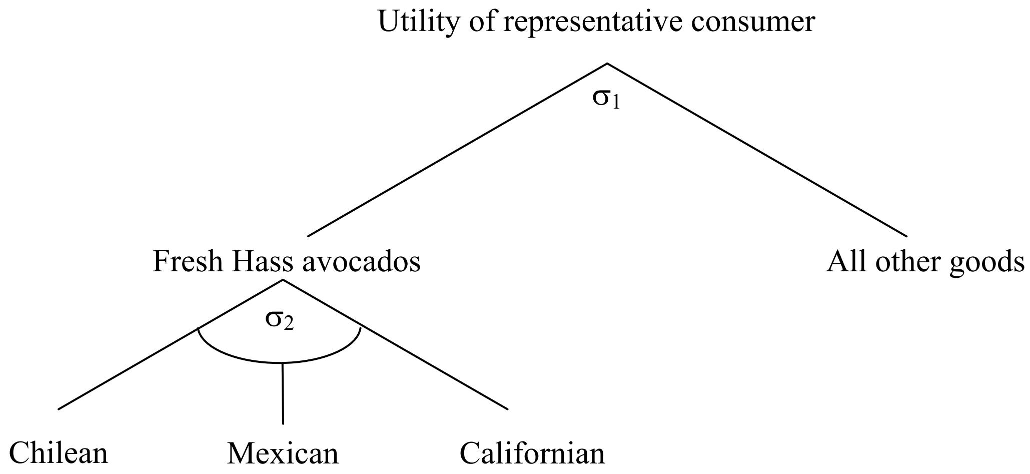
[15] The assumption of weak separability allows the demand for avocados to be specified as a function of avocado prices, an avocado price index, and total expenditure.

[16] In a homogeneous goods model, σ_2 would equal infinity, that is, avocados from the different supply regions would be perfect substitutes.

[17] The price of all other goods is held constant in the partial equilibrium model, and any change in the avocado price index represents a change in relative prices.

Figure 2

Preference structure for a representative consumer



Benchmark Market Data, Model Calibration,

The parameters of our model are set to correspond to the benchmark market equilibrium data. Details of the benchmark data, along with a discussion of the model calibration and sensitivity analysis of several of the model parameters, are given below.

Benchmark Data

Implementing the empirical model requires specifying a set of prices and quantities that represents an initial equilibrium. These values, shown in table 14, constitute the benchmark. All prices and quantities are averages from October 15, 2001 to October 15, 2003. During this period, Mexico was allowed to export only into Region A during Season 1. The advantage of using a multiyear base is that it reduces the chance of choosing an unusual year. A 2-year benchmark period is chosen, instead of a longer period, because of increased imports from Mexico and Chile in recent years.

During the benchmark period, risks from fruit fly and avocado pests are assumed to be zero due to the combination of compliance measures in Mexico and the seasonal and geographic restrictions. [18] The quantity data for California avocados are based on monthly shipment information provided by the Avocado Marketing Research and Information Center. [19] Quantities of avocados imported from Chile and Mexico are from U.S. Census Bureau monthly data. The benchmark data are averages of the annual quantities demanded, as shown in table 3, disaggregated between Seasons 1 and 2. Total consumption of fresh avocados in the United States is almost evenly split between the two seasons. California and Chile each provided about 40 percent of the avocados consumed during Season 1 and Mexico provided about 20 percent. California avocados dominate U.S. consumption during Season 2, accounting for 75 percent.

Wholesale price data are based on reports by USDA’s Agricultural Marketing Service (AMS). Wholesale avocado price data were available for Atlanta, Baltimore, Boston, Chicago, Dallas, Detroit, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco, Seattle, and St. Louis. In both seasons, wholesale prices of California avocados are substantially higher than prices of Chilean avocados in all demand regions, while Chilean and Mexican avocados have similar wholesale prices in Region A during Season 1. During the benchmark period, the unweighted average wholesale price for California avocados across our four demand regions was $1.48 per pound during Season 1 and $1.70 per pound during Season 2, while the average prices for avocados from Chile were $1.18 and $1.44 per pound, respectively.

California producer prices are FOB prices reported by the California Avocado Commission. Chilean producer prices are unit import prices reported by USDA’s Foreign Agricultural Service (FAS). Mexican producer prices are the average price paid by Mexican packers for fruit shipped to the United States (Orden and Peterson. 2005). Producer prices for avocados from California exceed those of Chile or Mexico during the benchmark period. In the benchmark data, California produces a larger quantity of avocados in Season 2 at higher producer and wholesale prices than in Season 1. Chile provides a larger quantity of exports during Season 1 than

[18] This zero-risk assumption does not affect our comparison of simulation results with the benchmark results under alternative rules and expanded exports.

[19] AMRIC was created by California State law in 1985 to provide the California avocado industry with daily inventory and shipment information to guide harvest/market strategies.

Table 14
Benchmark data in the model

	Supply region		
Quantity demanded	California	Chile	Mexico
Season 1		*Million pounds*	
Region A	14.115	12.869	58.247
Region B	12.794	12.002	0
Region C	56.209	53.156	0
Region D	32.696	30.182	0
Total Supply	115.814	108.209	58.247
Season 2			
Region A	61.490	18.335	0
Region B	18.329	5.485	0
Region C	91.598	27.384	0
Region D	58.780	17.401	0
Total Supply	230.197	68.605	0
Wholesale prices			
Season 1		*Dollars per pound*	
Region A	1.470	1.103	1.080
Region B	1.562	1.370	N/A
Region C	1.515	1.216	N/A
Region D	1.378	1.058	N/A
Season 2			
Region A	1.744	1.461	N/A
Region B	1.748	1.573	N/A
Region C	1.720	1.426	N/A
Region D	1.592	1.291	N/A
Producer prices			
Season 1	0.871	0.577	0.540
Season 2	1.101	0.599	N/A
System compliance costs			
Growers	N/A	N/A	0.081
Packers/Exporters	N/A	N/A	0.026

————continued

Table 14
Benchmark data in the model (continued)

	Demand region			
	Region A	*Region B*	*Region C*	*Region D*
Per-capita income				
Season 1	$16,249	$13,796	$14,450	$16,500
Season 2	$16,527	$14,072	$14,733	$16,854
	Millions			
Population	149.274	58.333	59.855	21.929

Sources: Demand quantities: averages of annual quantities shown in table 2 and separated between Seasons 1 and 2. Wholesale prices: Market News Archive, USDA Agricultural Marketing Service, *Wholesale Market Fruit Reports* (various issues). Producer prices: California avocado prices are FOB prices reported by the California Avocado Commission**.** Chilean producer prices are unit import prices reported by USDA's Foreign Agricultural Service (FAS). Mexican producer prices are the average price paid by Mexican packers for fruit shipped to the U.S., reported in Orden and Peterson (2005). Per capita income: State quarterly personal income from U.S. Department of Commerce, Bureau of Economic Analysis. Population: mid-year State population estimates from U.S. Census Bureau.

in Season 2, despite lower wholesale and (slightly) lower producer prices in the first Season.

The margin between producer and wholesale prices is derived by subtracting the benchmark producer price from the benchmark wholesale price. For example, the margins in Region A in Season 1 are \$0.60 per pound for California avocados, \$0.53 per pound for Chilean avocados, and \$0.54 per pound for Mexican avocados. The marketing margin for Mexican avocados includes the packers' costs of compliance with the systems approach. The margins for California and Chile are assumed to remain constant in all model simulations, while marketing margins for Mexican avocados adjust to changes in packers' per pound compliance costs.

Using the benchmark export volume, the calculated cost of compliance is \$0.081 per pound for Mexican avocado growers and \$0.026 per pound for Mexican packers/exporters. Compliance costs are approximately 15 percent of the Mexican producer price and 5 percent of the wholesale margin on Mexican avocados.

Model Calibration

The parameters in the supply and demand equations are chosen to replicate the initial equilibrium identified in the benchmark data while satisfying a set of elasticities obtained from the literature. A full description of the calibration procedures is provided by USDA/APHIS (2004a).

Demand Calibration: Little empirical evidence exists on the magnitude of demand elasticities for avocados. Carman and Craft (1998) estimated the inverse demand for California avocados using annual data from 1962 through 1995. They obtained a price flexibility of -1.33 when per capita consumption of California avocados equaled 1.01 pounds and the producer price of avocados, deflated by the consumer price index (1982-84 base), equaled 51.29 cents per pound. Because per capita consumption and the real producer price in our benchmark data differ from those used by Carman and Craft, their flexibility estimate must be adjusted. Using the parameter estimates reported in Carman and Craft (equation (10)), per capita consumption of California avocados of 1.198 pounds, and a real producer price of 56.31 cents per pound yield a price flexibility of -1.60, or a demand elasticity of -0.62.

Because the demand elasticity estimate derived from Carman and Craft is for producer prices, it must be adjusted to the wholesale level to be consistent with our model. The wholesale-level demand elasticity is obtained by multiplying the producer-level demand elasticity by the ratio of the wholesale price to the producer price.[20] In the benchmark data, the average ratio of wholesale price to producer price for California avocados across all markets and seasons is 1.63, yielding a wholesale-level demand elasticity of -1.02 for California avocados.

The value of the demand elasticity for California avocados is used to determine the values of the unknown demand parameters σ_1 and σ_2 in each region. However, with two unknown parameters, we need an additional elasticity estimate to calibrate the model. This could be either an elasticity estimate for Chilean or Mexican avocados or an aggregate demand elasticity for all avocados. Because no elasticity estimates are available for Chilean or Mexican avocados, we use the

[20] This assumes that the elasticity of substitution between avocados and all other inputs at the wholesale level is equal to zero (e.g., fixed margins). This assumption is consistent with the treatment of the marketing margins in the model.

Californian demand elasticity to estimate a consistent aggregate demand elasticity for avocados. We compute the aggregate demand elasticity by multiplying the wholesale-level demand elasticity of -1.02 for California avocados by California's share of the total supply, which equals 0.595 across regions and seasons. Thus, the implied aggregate wholesale-level demand elasticity is equal to -0.61. Using these two elasticity estimates, we obtain values of 0.6 and 1.85 for σ_1 and σ_2, respectively. These values are then used to determine the shift parameters in the nested CES utility function in order to replicate the quantities demanded in the initial benchmark data (see USDA/APHIS 2004a).

Supply Calibration: Values of two parameters are required to implement the supply equations in the model: the aggregate supply elasticity and the elasticity of transformation. The aggregate supply elasticity determines how easily total production can expand or contract as the avocado price index changes. In their study, Carman and Craft estimated that the supply elasticity for California avocados ranged from approximately 0.2 in the short run to a maximum of 1.3 in the long run. Romano (1998) used an aggregate supply elasticity of 0.35 for California avocados, which we use in this analysis. Mexican export supply is assumed to be very elastic, with a supply elasticity of 50.0. Less than 20 percent of the output from approved orchards was exported in the benchmark period, so additional quantities could be shifted into exports at little or no added cost. For Chile, the relevant aggregate supply elasticity is the export supply, not total supply. Assuming the same total supply elasticity as for California, and adjusting this value based on the percentage of Chilean production exported, we use an aggregate export supply elasticity of 0.64 for Chile (0.35/0.547). During the years 2000 - 2002, 54.7 percent of Chilean avocado production was exported.

The elasticity of transformation, which is equal to $1-\beta$ in equation (19), determines the ease with which avocado producers can shift their sales between the two seasons as relative producer prices between the periods change. Given small observed differences in the relative quantity of avocados sold across seasons, the elasticity of transformation is assigned a small value, 0.5, in the model. The values of the parameter δ for each region are chosen in order to replicate the seasonal supplies of avocados. Mexico is not allowed to export avocados to the United States during Season 2 in the benchmark data, which implies that $\delta_{.}$ must equal 1 in equation (29). In the simulations where this seasonal restriction is removed, $\delta_{.}$ is set equal to 0.4 for Mexico. This value matches the proportion of Mexico's worldwide exports during Season 1.

Modeling Consumer Preferences with the Removal of Import Restrictions: To simulate the change in import restrictions under the 2004 rule that allows expanded seasonal and geographic access for Mexican avocados, it is necessary to adjust the shift parameters of the CES utility function for Region A in Season 2, and for Regions B, C, and D in both periods, from the initial zero values used to denote the policy-induced zero consumption of Mexican avocados in the benchmark period. This raises the issue of how to adjust the preference parameter values.

A change in the shift parameters can be thought of as a "varietal effect" that reflects non-price influences on the relative demand for avocados from each of the supply regions. Even if avocados from the three supply regions were equal in price, demand for them would not be the same because of consumers' perceptions and preferences.

Following Venables (1987), we assume that with the change in import restrictions, shift parameter values for avocados from Mexico that are initially zero can be equated to the shift parameter values for Chilean avocados. In Regions B, C, and D during Season 1, the shift parameters for California avocados are equal to 0.4 and the shift parameters for both Chilean and Mexican avocados are equal to 0.3. The preference (varietal effect) for California avocados is based on initial shift parameters of approximately 0.6 and 0.4 for avocados from California and Chile. While the quantity market shares of California and Chilean avocados are almost equal, there is a wholesale price premium for California avocados. This implies a varietal effect towards California avocados, which may be a result of marketing activities by the California Avocado Commission or of consumer perceptions that fruit from California is fresher than fruit from Chile. Setting both the Chilean and Mexican shift parameters equal to 0.4—the initial value for Chilean avocados—would eliminate the existing varietal effect that favors California avocados. We believe that eliminating this preference for California avocados would be unrealistic.

In Season 2, the shift parameters for Mexican avocados in all regions are set equal to the initial shift parameters for Chilean avocados in the benchmark period. For example, in Region A, the initial shift parameter for avocados from Chile during Season 2 is equal to 0.1756. With the new rule, the shift parameter for avocados from Mexico is also set equal to 0.1756, and the preference parameter for California avocados is decreased by the same amount, since the coefficients must sum to 1 for each demand region in each season. A larger varietal effect for California avocados is justified in the second season due to seasonal production patterns. More fresh avocados are available from California than from Chile and Mexico during the summer months.

Sensitivity Analysis for Selected Model Parameters

There is uncertainty about the values of some of the parameters in the model. To incorporate this uncertainty, a sensitivity analysis is performed around three types of parameters: (1) yield and productivity losses incurred by California avocado producers as a result of any pest infestations (as described above), (2) the elasticities of substitution (and implicitly from these choices the own-price elasticities of demand), and (3) the elasticity of supply in each country. The mean and range of the parameters in the sensitivity analysis are shown in table 9 for the yield and losses of California producers and in table 15 for elasticities of substitution and supply. The parameter sensitivity analysis uses symmetric order-three Gaussian quadratures.[21] This procedure assumes that each uncertain parameter has an independent uniform distribution with known (or estimated) endpoints. A sample of parameters is drawn from these distributions and the model is resolved using each set of parameter values.

The procedure for drawing the sample of parameters is as follows: Let n be the number of parameters to be included in the sensitivity analysis. Then let $\Gamma_k = (\gamma_{k1}, \gamma_{k2}, \ldots, \gamma_{kn})$ be the kth quadrature point, where $k = 1, 2, \ldots, 2n$. Define an integer $r = 1, 2, \ldots, z$ such that z does not exceed $n/2$. For example, if n equals 5,

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[21] Stroud (1957) has shown that for a symmetric distribution, such as the uniform or triangular, the model needs to be resolved only $2n$ times, where n is the number of exogenous variables or parameters, in order to conduct a systematic sensitivity analysis. Arndt and Hertel (1997) have shown that systematic sensitivity analyses conducted using order-three quadratures are as accurate as higher order quadratures.

Table 15

Consumer substitution and producer supply parameters in the sensitivity analysis

Variable	Description	Mean	Minimum	Maximum
σ_1	Elasticity of substitution between avocados and all other goods	0.6	0.3	0.9
σ_2	Elasticity of substitution between avocados from different regions	1.85	1.25	2.45
aggsupply				
	California	0.35	0.175	0.525
	Chile	0.64	0.32	0.96
	Mexico	50	25	75

Note: the choice of σ_1 and σ_2 results in a mean own-price elasticity of -0.98, a minimum value (in absolute terms) of -0.59, and a maximum value of -1.37.

Source: Sensitivity analysis by authors.

then *r* would equal 2 because *r* cannot exceed 5/2. Elements of the Γ matrix are then chosen using the following formulas:

(1) $$\gamma_{k,2r-1} = \sqrt{2}\cos\left[\frac{(2r-1)k\pi}{n}\right] \text{ and}$$

(2) $$\gamma_{k,2r} = \sqrt{2}\sin\left[\frac{(2r-1)k\pi}{n}\right].$$

Note that if *n* is an odd number, then $\gamma_{kn} = (-1)^k$. The values of the parameters for each quadrature point are then determined using the formula:

(3) $$\Phi = \mu + \Gamma\sqrt{\Sigma},$$

where Φ is a (2*n* x *n*) matrix of values of parameters, μ is a (2*n* x *n*) matrix of the mean values of the parameters, Γ is a (2*n* x *n*) matrix defined above, and Σ is a (*n* x *n*) diagonal variance/covariance matrix for the parameters. Since all of the parameters are assumed to be independent, Σ is a diagonal matrix.

Simulation Analysis of Alternative Systems

To evaluate the risk and economic outcomes for alternative systems approaches, three scenarios are analyzed and compared to the initial benchmark results.

- Scenario 1 eliminates the geographic and seasonal restrictions on imports from Mexico under the 2001 rule while maintaining the other compliance measures of the systems approach. This corresponds to implementation of the 2004 rule.
- Scenario 2 eliminates the geographic and seasonal restrictions as well as eliminating fruit fly monitoring of orchards (field trapping) and quarantine requirements during harvests and packing (post-harvest safeguards) in Mexico. This is assumed to raise the probability of a fruit fly infestation during pre- or post-harvest (prob1 in equation 20) from its systems approach level (2.5E-06) to its level without the risk mitigation measures (5.5E-04), as shown in table 5. Other fruit fly and avocado-specific pest-risk probabilities are assumed to remain at their systems approach levels, because inspections continue in packing plants and at the U.S. border.
- Scenario 3 removes all compliance measures that have been applied to avocado imports from Mexico. The risk probabilities (prob1-prob4 and prob6 in equation 20) are assumed to be at their levels for no risk-mitigation measures (given in tables 5-8).

In each scenario, we consider the outcomes under the average and maximum (high) risk probability levels given in the tables.

The three scenarios imply different compliance costs for Mexican growers and packers/exporters. In the first two scenarios, compliance costs per pound will depend on the equilibrium export quantities. In scenario 2, eliminating all fruit fly monitoring will also reduce the direct costs of Sanidad inspections. Approximately one-third of the $1,283,772 cost for technical labor, or $427,924, was estimated in our field interviews to be incurred for fruit fly monitoring. Adding the cost of traps ($26,000) and chemicals ($158,147) yields a total cost of $612,071 for fruit fly monitoring for a single annual pest survey. Since inspections are required twice per year under the 2004 rule, the total cost reduction from eliminating fruit fly monitoring for the Mexican growers is assumed to be $1,224,142. Subtracting this from our earlier estimates of the cost of pest surveys of $3,568,144 yields $2,344,002, or $85.58 per hectare. Thus, while the cost of pest surveys increases with the requirement for two surveys per year, the increase would be much smaller if the costs of monitoring fruit flies were eliminated. For Mexican packers/exporters, eliminating the need for packing plant quarantine for fruit flies would mean that the $0.005/lb cost for upgrading their facilities would no longer be necessary. In scenario 3, all of the systems approach requirements are eliminated. Mexican avocado growers and packers/exporters thus would not incur any compliance costs to export to the United States.

Pest Outbreaks: Frequencies, Costs of Compliance, and Costs of Control

A critical aspect of the simulation equilibrium outcomes is the frequency of pest outbreaks in the United States. The results depend on the risk probability levels for the assumed compliance measures and the quantity of exports of Mexican avocados to pest-susceptible regions in the United States. The frequencies (number per season) of expected pest outbreaks are shown in table 16 for the equilibrium outcomes in the three scenarios. Simulated per pound cost of compliance for Mexican growers and packers/exporters, and the expected costs of pest control (CP) in California avocado orchards, are also shown.

For fruit flies, the frequency infestation is very low (no more than 4.0E-06 per year) in scenario 1. The frequency increases by an order of magnitude (to at most 3.6E-05) under the high pest-risk probabilities. Eliminating the compliance measures specific to fruit flies in Mexico (scenario 2) raises the frequency of outbreaks in the United States by two orders of magnitude, and eliminating all of the systems approach pest control compliance measures (scenario 3) raises these risks another two orders of magnitude. The estimated frequency of a fruit fly infestation reaches a maximum of 0.11 in scenario 3 in Region C during Season 1. For Southern California (Region D), the expected cost of controlling the fruit fly infestations never exceeds $0.00022 per pound when averaged over the quantity of avocados produced under scenario 3. The cost of fruit fly control for expected outbreaks due to importing avocados from Mexico remains low in regions B and C (less than f $124,000 for the worst case of high pest-risk probabilities in scenario 3) and is not shown in table 16.

The expected frequencies are also quite low for infestations of avocado-specific pests due to imports from Mexico under the 2004 rule (scenario 1). Among avocado pests, the frequency of an outbreak is highest for stem weevils by two orders of magnitude. Stem weevil outbreak frequencies also increase by an order of magnitude under the high pest-risk probabilities (from 4.9E-03 to 4.1E-02). The avocado-specific pest frequencies are not affected directly by removing the fruit fly compliance measures in scenario 2, [22] but the outbreak frequencies rise by two orders of magnitude when all compliance measures are eliminated. For the stem weevils, expected frequency of an outbreak reaches approximately 0.75 per season under the average pest-risk probabilities and 6.4 per season under the high pest-risk probabilities. Thus, without any systems approach compliance measures, avocado stem weevil outbreaks resulting from imports from Mexico are likely, possibly multiple times in a typical year. The expected frequencies of other avocado pest outbreaks remain two orders of magnitude smaller.

The alternative compliance requirements under scenarios 1-3 have substantial implications for the costs borne by Mexican avocado growers and packers/exporters and the costs of avocado pest control and production losses borne by California producers. In scenario 1, Mexican compliance costs are estimated to be $0.037 per pound for growers and $0.019 per pound for packers/exporters, a total of $0.056 per pound, compared with a total of $0.107 per pound of avocados exported in the benchmark.. These per pound compliance costs are 45.7 percent of the benchmark costs for growers and 73.1 percent of the benchmark costs for packers/exporters. Although compliance requirements increase with year-round shipping from $6.267 million to $11.644 million, the volume of exports increases enough that per pound costs are sharply lower.

When specific compliance measures for fruit flies are eliminated in scenario 2, the per pound cost of compliance falls still farther for both growers and packers/exporters (to $0.031 per pound and $0.014 per pound, respectively). This additional decrease of $0.011 per pound arises primarily from a $2.23-million

[22] There is a slight increase in these probabilities due to a small increase in the equilibrium quantity of avocado exports entering Regions D in scenario 2 compared with scenario 1.

Table 16

Frequency of pest outbreaks and compliance and pest control costs under alternative systems

	Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
Frequency of outbreak	*Risk probability level*					
	Average	High	Average	High	Average	High
Fruit flies						
Season 1						
Region B	1.0E-06	7.0E-06	1.6E-04	1.4E-03	2.5E-03	2.1E-02
Region C	4.0E-06	3.6E-05	8.7E-04	7.4E-03	1.3E-02	1.1E-01
Region D	2.0E-06	2.0E-05	4.9E-04	4.1E-03	7.5E-03	6.4E-02
Season 2						
Region B	1.0E-06	5.0E-06	1.2E-04	1.0E-03	1.9E-03	1.6E-02
Region C	3.0E-06	3.2E-05	7.6E-04	6.4E-03	1.2E-02	9.8E-02
Region D	2.0E-06	2.1E-05	5.0E-04	4.2E-03	7.6E-03	6.5E-02
Seed weevil						
Season 1	1.9E-05	1.8E-04	1.9E-05	1.8E-04	6.1E-03	5.7E-02
Season 2	1.9E-05	1.8E-04	2.0E-05	1.8E-04	6.2E-03	5.8E-02
Stem weevil						
Season 1	4.9E-03	4.1E-02	4.9E-03	4.1E-02	7.5E-01	6.4E+00
Season 2	4.9E-03	4.2E-02	5.0E-03	4.2E-02	7.6E-01	6.5E+00
Seed moth						
Season 1	1.0E-06	6.0E-06	1.0E-06	6.0E-06	1.8E-03	1.8E-02
Season 2	1.0E-06	6.0E-06	1.0E-06	6.0E-06	1.8E-03	1.8E-02
Mexican compliance costs						
Growers	0.037		0.031		0.000	
Packers/Exporters	0.019		0.014		0.000	
Costs for California avocado orchards						
Fruit flies	0.0	0.0	1.6E-06	7.5E-06	2.5E-05	2.2E-04
Seed weevil	2.6E-07	2.4E-06	2.6E-07	2.4E-06	8.2E-05	7.6E-04
Stem weevil	6.5E-05	5.5E-04	6.6E-05	5.6E-04	1.0E-02	8.6E-02
Seed moth	0.0	0.0	0.0	0.0	2.4E-05	2.4E-04

Source: Derived by the authors from model simulations.

reduction in compliance costs compared with scenario 1, as the quantity of exports only slightly increases in scenario 2.

When all measures are removed in scenario 3, the associated compliance costs for Mexican growers and packers/exporters are also eliminated, but with higher expected frequencies of pest outbreaks in the United States. The expected cost of control measures for California orchards remain low for seed weevil and seed moth outbreaks. However, pest control costs for the relatively frequent outbreaks of stem weevil become substantial. These costs are estimated to be $0.01 per pound in scenario 3 with average pest-risk probabilities and $0.086 per pound with high pest-risk probabilities. Thus, terminating all measures raises pest control costs for California avocado producers to the same magnitude per pound as the compliance costs for Mexican avocado producers before the 2004 rule was implemented. In addition, California growers suffer output losses due to pest-damaged fruit.

Market Equilibrium and Welfare With Average Pest-Risk Probabilities

Producer and wholesale prices, quantities demanded and supplied, producer gross revenue, Mexican compliance costs, and expected pest-related costs of control incurred by California avocado growers due to imports from Mexico are shown for the benchmark and the three simulation scenarios in table 17. These results are for simulations based on the average pest-risk probabilities estimated by APHIS.

In scenario 1, there is a sharp net decline in demand for avocados from California and Chile. This is reflected in lower producer and wholesale prices and quantities consumed. Producer prices for California and Chilean avocados decline over 30 percent in each period (slightly more in period 2), and annual equilibrium quantity demanded and supplied falls by 11.3 percent for California avocados and by 17.1 percent for avocados from Chile. Annual producer gross revenue in California declines from $354.298 million to $213.155, or by 39.8 percent. For Chile, producer gross revenue (export earnings evaluated at producer prices) similarly falls from $103.493 million to $63.226 million. Expected pest-control costs for California avocado growers due to imports from Mexico are only $20,000.

With the increased seasonal and geographic access allowed under scenario 1, annual exports from Mexico increase by 250 percent, from 58.247 to 206.956 million pounds. Due to lower producer and wholesale price, Mexican exports are higher in Season 1 (122.697 million pounds) than in Season 2 (84.259 million pounds). [23]

At the producer level, the price of avocados in Mexico declines from $0.540 per pound in the benchmark to $0.507 in Season 1 and $0.537 in Season 2 (table 17). The larger price decrease in Season 1 is due to the seasonal pattern of Mexican avocado exports and U.S. consumption. With lower U.S. per capita consumption and higher Mexican exports in Season 1, an expansion of Mexican exports leads to a larger decrease in the export price of Mexican avocados in Season 1 than in Season 2. The net export prices received by producers also depend on their compliance costs. With expanded exports, the per pound compliance costs fall. If the growers' per pound compliance costs in the benchmark and scenario 1 (in tables 14 and 16, respectively) are subtracted from the corresponding producer prices in table 17, the net price received by Mexican avocado growers rises in each season:

[23] The equilibrium quantity of avocados from Mexico consumed in Region A in Season 1 falls to 55.317 million pounds as avocados from California and Chile become relatively less expensive. In regions B, C and D, where imports from Mexico were previously not allowed, consumption increases from zero to 67.383 million pounds despite falling prices for other avocados. The regional results are not shown in table 17 but are available from the authors on request.

Table 17

Equilibrium prices and quantities demanded and supplied under alternative systems: Average risk probabilities

		Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
		Simulation outcomes and standard deviations from sensitivity analysis					
	Base values	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Producer prices	*Dollars per pound*						
Season 1							
California	0.871	0.587	0.033	0.584	0.033	0.577	0.036
Chile	0.577	0.400	0.023	0.398	0.023	0.390	0.023
Mexico	0.540	0.508	0.014	0.502	0.014	0.470	0.013
Season 2							
California	1.101	0.748	0.056	0.746	0.056	0.743	0.057
Chile	0.599	0.478	0.040	0.476	0.040	0.471	0.041
Mexico	0.540	0.537	0.019	0.532	0.020	0.505	0.021
Wholesale prices							
Season 1							
Region A							
California	1.470	1.186	0.033	1.183	0.033	1.176	0.036
Chile	1.103	0.926	0.023	0.924	0.023	0.916	0.023
Mexico	1.080	1.041	0.014	1.029	0.014	0.984	0.013
Region B							
California	1.562	1.278	0.033	1.275	0.033	1.268	0.036
Chile	1.370	1.193	0.023	1.191	0.023	1.184	0.023
Mexico	1.080	1.041	0.014	1.029	0.014	0.984	0.013
Region C							
California	1.515	1.231	0.033	1.228	0.033	1.221	0.036
Chile	1.216	1.039	0.023	1.037	0.023	1.030	0.023
Mexico	1.080	1.041	0.014	1.029	0.014	0.984	0.013

———continued

Table 17

Equilibrium prices and quantities demanded and supplied under alternative systems: Average risk probabilities (continued)

		Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
		Simulation outcomes and standard deviations from sensitivity analysis					
	Base values	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Quantities demanded and supplied	*Million pounds*						
Season 1 (total supply)	**282.269**	**312.427**	**4.856**	**313.552**	**4.617**	**318.026**	**4.111**
California	115.815	102.452	3.036	102.268	3.044	100.814	3.238
Chile	108.208	87.278	2.940	87.028	2.865	86.112	2.883
Mexico	58.247	122.697	4.489	124.256	4.442	131.10	4.546
Season 2 (total supply)	**298.802**	**348.093**	**10.630**	**348.989**	**10.396**	**352.095**	**10.122**
California	230.196	204.491	6.311	204.338	6.260	202.619	6.420
Chile	68.605	59.343	2.734	59.229	2.694	58.888	2.726
Mexico	0.000	84.259	5.518	85.422	5.522	90.588	5.796
Annual (total supply)	**581.071**	**660.520**	**15.296**	**662.541**	**14.825**	**670.121**	**13.915**
California	346.011	306.943	8.890	306.606	8.846	303.433	9.162
Chile	176.813	146.621	5.323	146.257	5.204	145.000	5.248
Mexico	58.247	206.956	9.965	209.678	9.924	221.688	10.300
Producer gross revenue	*Million dollars*						
Season 1							
California	100.897	60.160	3.200	59.729	3.221	58.194	3.496
Chile	62.398	34.887	1.499	34.608	1.451	33.590	1.244
Mexico	31.453	62.329	1.137	62.336	1.071	61.682	1.027
Season 2							
California	253.401	152.995	12.690	152.379	12.411	150.524	12.307
Chile	41.095	28.339	2.946	28.192	2.901	27.761	2.845
Mexico	0.000	45.224	4.437	45.402	4.467	45.788	4.671
Annual total							
California	354.298	213.155	15.063	212.108	14.777	208.718	14.771
Chile	103.493	63.226	3.923	62.800	3.843	61.351	3.598
Mexico	31.453	107.553	5.257	107.738	5.267	107.470	5.398
Mexican compliance costs							
Growers	4.726	7.716	0.105	6.496	0.105	0.000	0.000
Packers	1.541	3.928	0.160	2.918	0.110	0.000	0.000
California expected cost of control	0	0.020	0.008	0.021	0.008	3.091	1.243

Source: Derived by the authors from model simulations.

from $0.459 per pound in the benchmark to $0.461 per pound in Season 1 and $0.500 in Season 2. Mexican annual producer gross revenue increases from $31.453 million to $107.553 million.

The net welfare effects of removing the seasonal and geographic restrictions on avocado exports from Mexico while retaining the other systems approach measures are shown in table 18. Expected producer surplus for California avocado growers declines by $107.651 million. This estimate takes into account the impact of expanded trade, which leads to lower market prices for California avocados, and the effects from small expected pest-control costs and output losses due to pest damage, which leads to lower net producer prices for Californian growers. Pest-control costs for fruit flies for other U.S. crops are negligible. Producer surplus also declines by $25.069 million for Chilean avocado growers, but increases by $3.108 million for Mexican avocado growers.[24] The smaller increase in Mexican producer surplus is due to elastic export supply used in this analysis, which implies that more of the benefits of the policy change are passed on to U.S. consumers. This can be seen by the estimated total gain in equivalent variation of $179.443 million for U.S. consumers across all regions and seasons. U.S. net welfare increases by $71.791 million for scenario 1.

In our second scenario, all monitoring of fruit flies in orchards and quarantine requirements during harvests and packing are eliminated along with all seasonal and geographic restrictions on Mexican avocado exports. This leads to a further reduction in Mexican compliance costs, while the expected cost of pest control in California remains low. Mexican exports expand by 2.722 million pounds (1.01 percent) compared with scenario 1, which also lowers per pound compliance costs slightly, from $0.056 to $0.045 per pound. Wholesale prices for Mexican avocados fall by about $0.01, mainly in response to the lower compliance costs. Gross revenue for Mexican growers increases by $185,000, their revenue net of their compliance costs rises by $1.405 million, and producer surplus increases by $90,000. Effects on quantities supplied and producer and wholesale prices of avocados from California and Chile are relatively small. Producer surplus declines an additional $832,000 for California growers and $272,000 for Chilean growers compared with scenario 1. U.S. consumers benefit from an additional increase of $2.586 million in equivalent variation, and net U.S. welfare increases by $1.756 million, to $73.547 million, compared with scenario 1. Thus, while most of the increased trade and net welfare gains come from the removal of seasonal and geographic restrictions, there are additional net gains—with little additional pest-risk costs or losses to U.S. producers—from eliminating the compliance measures directed specifically at fruit flies.

In our third scenario, all systems approach measures are eliminated, with associated increases in fruit fly and avocado-specific pest risks. Compliance costs in Mexico are eliminated, but pest risks are high enough that expected control costs for California avocado growers jump to $3.091 million. Producer and wholesale prices of California avocados are similar to those in scenario 1, but the quantity of avocados supplied annually by California falls by 3.510 million pounds. Californian gross producer revenue falls by $4.437 million compared with the first scenario, producer revenue less control costs falls by $7.508 million, and producer surplus falls by an additional $5.196 million. Chile also experiences a loss of exports, gross revenue, and producer surplus compared with scenario 1. Producer

[24] The increase in producer surplus for Mexican avocado growers does not take into account any increases in domestic avocado prices in Mexico or export prices to other countries that arise from the shift in sales from these other markets to the U.S. market. Thus, our estimate underestimates the increases in welfare to Mexican producers.

Table 18

Producer and consumer welfare under alternative systems: Average risk probabilities

	Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
	Simulation outcomes and standard deviations from sensitivity analysis					
	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Welfare change	*Million dollars*					
Producer surplus						
California	-107.651	15.755	-108.483	15.759	-112.847	16.103
Chile	-25.069	4.693	-25.341	4.701	-26.269	4.751
Mexico	3.108	0.981	3.198	1.006	3.607	1.124
Equivalent variation						
Season 1						
Region A	9.350	0.967	10.074	0.991	12.895	1.091
Region B	7.676	0.333	8.541	0.503	8.744	0.404
Region C	30.537	1.849	31.212	1.825	33.756	1.948
Region D	14.882	1.192	15.336	1.192	16.508	1.264
Season 2						
Region A	32.827	4.112	32.421	4.854	33.259	3.942
Region B	10.116	1.507	9.951	1.441	10.381	1.458
Region C	46.621	6.062	46.825	6.041	48.976	6.047
Region D	27.434	3.962	27.668	3.951	28.79	3.989
U.S. annual total	179.443	18.917	182.029	19.547	193.308	19.136
Other cost of control – fruit flies	6.5E-06	3.3E-07	0.001	7.3E-05	0.015	0.002
Net U.S. welfare change	71.791	6.290	73.547	5.523	80.442	6.156

Source: Derived by the authors from model simulations.

and wholesale prices of Mexican avocados decline with zero compliance costs, and Mexican avocado exports increase by 14.732 million pounds compared with scenario 1. Gross producer revenue in Mexico decreases by $83,000, but revenue net of compliance costs increases by $7.633 million and producer surplus increases by $499,000. U.S. consumers again experience net gains: avocado consumption increases to 670.121 million pounds (9.601 million pounds more than scenario 1), and equivalent variation increases to $193.308 million, which is $13.865 million higher than in scenario 1. Net U.S. welfare increases by $80.442 million versus an increase of $71.791 million in scenario 1. Thus, there is a substantial additional domestic welfare gain associated with eliminating all of the systems approach measures, at the average pest-risk probabilities estimated by APHIS, in spite of the significant pest-related losses to California avocado growers.

Market Equilibrium and Welfare With High Pest-Risk Probabilities

The market equilibrium and welfare results are presented in tables 19 and 20 for the three simulations using the high pest-risk probabilities estimated by APHIS. Estimated pest risks remain very low in scenarios 1 and 2. In these two scenarios, California growers receive slightly lower net prices than in the corresponding scenarios under average pest risks, as expected costs of pest control (primarily for fruit flies) increase to $170,000 (scenario 1) and $174,000 (scenario 2), respectively. Quantities of avocados produced by California growers, and their producer surplus, decline slightly compared with the corresponding scenarios under average pest risks. Producers in Chile and Mexico benefit slightly from the reduced avocado supply from California, with slight increases in producer gross revenue and producer surplus compared with the corresponding average risk simulations.

The increased probability of pest risks and related costs has a negative net effect on consumers and net U.S. welfare. When trade is opened up with higher risks of pest damage, gains to U.S consumers are smaller and the losses to California avocado growers are larger. While these effects are quite small in scenarios 1 and 2, they do show that the higher pest risk is detrimental economically.

Risk impacts are demonstrated vividly in scenario 3 using the high pest-risk probabilities. In this scenario, the expected per pound control costs for California avocado growers increase to $0.086 (table 16). Equilibrium prices received by California producers increase to $0.624 in Season 1 and $0.799 in Season 2, compared with $0.577 and $0.743 using the average risk probabilities. With the higher pest-control costs, the net price received by California producers falls to $0.538 per pound from $0.567 per pound in Season 1 and to $0.713 per pound from $0.733 in Season 2. The supply of California avocados declines in response to the falling net producer prices as well as the damage to fruit from the avocado pests. The equilibrium quantity supplied by California growers falls to 290.008 million pounds, compared with 303.433 million pounds supplied in scenario 3 using the average risk probabilities. While gross revenue is higher for California growers in scenario 3 with high risk probabilities than in the same scenario with average risk probabilities, net revenue falls from $205.627 million to $189.843 million. The producer surplus of California growers declines by an additional $7.128 million for scenario 3 with high pest risk compared with scenario 3 with average risk. The decline in California production due to higher pest-control costs and fruit damage has a negative effect on U.S. consumers. Wholesale prices for California avocados

Table 19

Equilibrium prices and quantities demanded and supplied under alternative systems: High risk probabilities

		Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
		Simulation outcomes and standard deviations from sensitivity analysis					
	Base values	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Producer prices	*Dollars per pound*						
Season 1							
California	0.871	0.588	0.033	0.584	0.034	0.624	0.050
Chile	0.577	0.400	0.023	0.398	0.023	0.396	0.022
Mexico	0.540	0.508	0.014	0.502	0.014	0.469	0.014
Season 2							
California	1.101	0.749	0.056	0.746	0.056	0.799	0.075
Chile	0.599	0.478	0.040	0.476	0.040	0.485	0.043
Mexico	0.540	0.537	0.019	0.532	0.020	0.510	0.023
Wholesale prices							
Season 1							
Region A							
California	1.470	1.186	0.033	1.183	0.034	1.223	0.050
Chile	1.103	0.926	0.023	0.924	0.023	0.922	0.022
Mexico	1.080	1.041	0.014	1.029	0.014	0.982	0.014
Region B							
California	1.562	1.278	0.033	1.275	0.034	1.315	0.050
Chile	1.370	1.193	0.023	1.191	0.023	1.189	0.022
Mexico	1.080	1.041	0.014	1.029	0.014	0.982	0.014
Region C							
California	1.515	1.231	0.033	1.228	0.034	1.268	0.050
Chile	1.216	1.039	0.023	1.037	0.023	1.035	0.022
Mexico	1.080	1.041	0.014	1.029	0.014	0.982	0.014

———continued

Table 19

Equilibrium prices and quantities demanded and supplied under alternative systems: High risk probabilities (continued)

		Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
		Simulation outcomes and standard deviations from sensitivity analysis					
	Base values	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Wholesale prices	*Dollars per pound*						
Region D							
California	1.378	1.095	0.033	1.092	0.034	1.132	0.050
Chile	1.058	0.881	0.023	0.879	0.023	0.877	0.022
Mexico	1.080	1.041	0.014	1.029	0.014	0.982	0.014
Season 2							
Region A							
California	1.744	1.392	0.056	1.389	0.056	1.442	0.075
Chile	1.461	1.340	0.040	1.338	0.040	1.347	0.043
Mexico	1.080	1.070	0.019	1.059	0.019	1.024	0.023
Region B							
California	1.748	1.395	0.056	1.393	0.056	1.446	0.075
Chile	1.573	1.451	0.040	1.450	0.040	1.459	0.043
Mexico	1.080	1.070	0.019	1.059	0.019	1.024	0.023
Region C							
California	1.720	1.368	0.056	1.365	0.056	1.418	0.075
Chile	1.426	1.305	0.040	1.303	0.040	1.312	0.043
Mexico	1.080	1.070	0.019	1.059	0.019	1.024	0.023
Region D							
California	1.592	1.240	0.056	1.237	0.056	1.291	0.075
Chile	1.291	1.170	0.040	1.168	0.040	1.177	0.043
Mexico	1.080	1.070	0.019	1.059	0.019	1.024	0.023

———continued

Table 19

Equilibrium prices and quantities demanded and supplied under alternative systems: High risk probabilities (continued)

		Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
		Simulation outcomes and standard deviations from sensitivity analysis					
	Base values	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Quantities demanded and supplied	*Million pounds*						
Season 1 (total supply)	**282.269**	**312.414**	**6.107**	**313.539**	**4.621**	**316.197**	**4.774**
California	115.815	102.418	3.011	102.233	3.045	95.583	4.332
Chile	108.208	87.282	2.862	87.033	2.864	86.862	2.800
Mexico	58.247	122.714	4.476	124.273	4.447	133.752	5.536
Season 2 (total supply)	**298.802**	**348.060**	**8.743**	**348.955**	**10.402**	**347.276**	**11.346**
California	230.196	204.437	6.241	204.283	6.262	194.425	7.890
Chile	68.605	59.349	2.692	59.235	2.694	59.818	2.887
Mexico	0.000	84.274	5.500	85.437	5.527	93.033	6.793
Annual (total supply)	**581.071**	**660.474**	**15.124**	**662.494**	**14.835**	**663.473**	**15.848**
California	346.011	306.855	8.803	306.516	8.850	290.008	11.756
Chile	176.813	146.631	5.200	146.268	5.204	146.680	5.322
Mexico	58.247	206.988	9.934	209.710	9.934	226.785	12.291
Producer gross revenue	*Million dollars*						
Season 1							
California	100.897	60.172	3.186	59.739	3.225	59.690	4.274
Chile	62.398	34.892	1.515	34.613	1.452	34.383	1.389
Mexico	31.453	62.335	1.112	62.342	1.072	62.679	1.317
Season 2							
California	253.401	153.031	12.517	152.412	12.424	155.409	14.599
Chile	41.095	28.347	2.931	28.200	2.903	29.018	3.317
Mexico	0.000	45.235	4.434	45.412	4.471	47.459	5.418
Annual total							
California	354.298	213.202	12.916	212.151	14.793	215.100	17.823
Chile	103.493	63.239	3.299	62.814	3.847	63.401	4.282
Mexico	31.453	107.570	4.572	107.754	5.272	110.138	6.486
Mexican compliance costs							
Growers	4.726	7.716	0.105	6.496	0.105	0.000	0.000
Packers	1.541	3.928	0.159	2.918	0.110	0.000	0.000
California expected cost of control	0	0.170	0.069	0.174	0.070	25.257	10.019

Source: Derived by the authors from model simulations.

Table 20

Producer and consumer welfare under alternative systems: High risk probabilities

	Scenario 1: Unlimited seasonal and geographic access with compliance measures		Scenario 2: Unlimited access without fruit fly compliance measures		Scenario 3: Unlimited access without compliance measures	
	Simulation outcomes and standard deviations from sensitivity analysis					
	Simulation	St. dev.	Simulation	St. dev.	Simulation	St. dev.
Welfare change	*Million dollars*					
Producer surplus						
California	-107.699	15.768	-108.533	15.772	-119.975	18.818
Chile	-25.061	4.693	-25.333	4.701	-24.957	4.797
Mexico	3.109	0.982	3.199	1.006	3.788	1.207
Equivalent variation						
Season 1						
Region A	9.345	0.967	10.069	0.991	12.099	1.216
Region B	7.844	0.308	8.427	0.479	8.276	0.497
Region C	30.827	1.895	31.47	1.802	31.641	2.389
Region D	15.182	1.175	15.355	1.199	15.087	1.570
Season 2						
Region A	33.126	4.288	31.883	4.964	29.605	4.744
Region B	10.098	1.454	9.794	1.492	9.47	1.608
Region C	46.580	6.102	47.209	6.064	44.057	7.202
Region D	27.700	3.994	27.668	4.006	25.441	4.771
U.S. annual total	180.702	19.115	181.875	19.694	175.675	22.971
Other cost of control – fruit flies	6.1E-05	3.3E-07	0.007	3.7E-05	0.124	0.002
Net U.S. welfare change	73.002	6.120	73.349	5.737	55.562	12.735

Source**:** Derived by the authors from model simulations.

are about $0.05 per pound higher using the high pest-risk probabilities compared with the average pest-risk probabilities. Because of the higher wholesale prices, consumption of California avocados is further reduced by 13.425 million pounds (from 303.433 million to 290.008 million pounds), and there is a 6.648 million pound smaller increase in total avocado consumption (670.121 million to 663.478 million pounds), compared with scenario 3 with average pest risks. The reduction in consumption leads to a $17.633 million smaller gain in equivalent variation ($175.675 million versus $193.308 million). In addition, the increase in consumer welfare in scenario 3 is lower than the increases in scenarios 1 or 2. Thus when pest risks increase, both consumers and producers are worse off with elimination of the systems approach measures than they are if seasonal and geographic restrictions are removed while the systems approach measures are retained (at least for the avocado-specific pests). In scenario 3, the net U.S. welfare gain is $55.562 million, $24.88 million less than the net welfare gain in scenario 3 using the average pest risk probabilities. This is the smallest net U.S. welfare gain in all of the scenarios and risk levels considered.

Foreign avocado producers, however, are net beneficiaries in scenario 3 under high pest-risk probabilities compared with average risk probabilities. The increase in producer surplus for Mexican growers is $181,000 larger, while the decrease in producer surplus for Chilean growers is $1.312 million smaller.

Summary and Conclusion

In this report, a static, multiseason, partial equilibrium model has been developed to evaluate the economic effects of importing fresh Hass avocados from approved orchards in Mexico into the United States. Scenarios without geographic or seasonal restrictions are evaluated under alternative measures to mitigate pest risks.

Until 1997, phytosanitary restrictions precluded entry of Mexican avocados into the conterminous United States. In November 1997, fresh Hass avocados from Mexico were allowed entry into 19 Northeastern States and the District of Columbia during a 4-month period from November through February. In 2001, the area approved for import was expanded by an additional 12 States, and the period of importation was extended to 6 months, October 15 to April 15. The most recent ruling, in November 2004, effectively eliminates all geographic and seasonal restrictions by allowing year-round importation of Mexican avocados into all States by 2007. The progression of these USDA phytosanitary rules illustrates that technical trade restrictions can be eased when the risk issues can be sharply delineated and addressed and governments are firmly committed to negotiations. Easing the import ban on Mexican avocados under a systems approach to pest-risk management has facilitated trade by opening the U.S. market to Mexican producers and resulted in net welfare gains to U.S. consumers, with little added pest risk to U.S. producers.

The model articulated in this report builds on the one used by USDA/APHIS in the economic analysis of the full opening of the U.S. market under the November 2004 rule. That analysis was completed under the assumption that there was no risk of pest transmission to the United States as long as the stipulated measures remained in effect in Mexico and at the U.S. border.

The contribution of this report is to extend the earlier analysis to explicitly consider pest risks, the costs of compliance in Mexico with the systems approach, and costs to U.S. producers for pest control and production losses in the event of a pest infestation. The model incorporates three supply regions (Southern California, Chile, and Mexico), substitution possibilities between two seasons (winter and summer), and four U.S. demand regions. Pest risks and related domestic costs are derived from USDA/APHIS studies, and Mexican compliance costs were investigated during field research in the avocado exporting state of Michoacán. Three alternative compliance scenarios are evaluated with the model: (1) removal of all seasonal and geographic restrictions while maintaining all other compliance measures (2004 rule), (2) further removal of the compliance measures directed specifically toward Mexican fruit flies, and (3) elimination of all systems approach requirements.

Our simulations show that the substantially expanded trade anticipated under the November 2004 rule lowers Mexican per unit compliance costs from $0.107 per pound to $0.056 per pound of avocados exported. Because pest risks are low with the measures still in place, our estimated annual net U.S. welfare gain from eliminating all geographic and seasonal restrictions is approximately $72 million, similar to the earlier APHIS assessment.

When the systems approach measures related directly to reducing Mexican fruit fly infestations (field trapping and post-harvest quarantine requirements in Mexico) are eliminated along with the seasonal and geographic restrictions, we calculate there are further compliance cost savings with little increase in pest risks. Compliance costs of Mexican growers and packers/exporters fall by another $0.011 per pound of avocados exported. The pest risk to U.S. producers increases by two orders of magnitude but remains low in absolute terms, and there is an additional net welfare gain of nearly $2 million for the United States under the range of risk probabilities we apply.

The outcome is less certain if the systems approach is completely abandoned, with all pest risk mitigation measures against fruit flies and the targeted avocado pests eliminated. In the best case, based on the APHIS average pest-risk probabilities with no control measures, there is an additional gain in net U.S. welfare of $8.7 million compared with eliminating only the seasonal and geographic restrictions. In this case, expanded consumer benefits more than offset additional pest-related losses to California producers of nearly $5 million. However, using the maximum APHIS pest-risk probabilities, infestations due to imported avocados become frequent enough that California producers lose an additional $12 million in producer surplus compared with allowing year-round access to all States with the measures still in place. Consumer welfare gains are also reduced by more than $3.5 million in this worst case compared with retaining the systems approach measures because pest-related productivity losses in California reduce the domestic supply of avocados and lead to higher consumer prices. Overall, the net gain in U.S. welfare is $16.2 million less than the net welfare gain from eliminating only the geographic and seasonal restrictions.

Our analysis of these alternative pest-risk management import policies suggests three broad conclusions. First, the gains from the USDA decision to allow imports of Mexican avocados under a systems approach that does not include seasonal or geographic restrictions hold up when pest risks and related costs are incorporated into the analysis. Second, there may be modest additional gains from further modification of the systems approach to reduce compliance costs associated with fruit fly control measures. Third, abandoning the systems approach completely would be a less conservative decision in terms of pest-risk or economic criteria. That is, it may yield a net gain in U.S. welfare, but at a cost of higher pest-related control costs and productivity losses borne by California producers. Moreover, our knowledge of pest-risk probabilities is not precise enough to rule out a smaller gain in U.S. welfare compared with scenarios when some or all of the measures are retained.

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