Avocado Pests and Avocado Trade

Everett B. Peterson and David Orden

This article evaluates the effects of a November 2004 phytosanitary rule that removed seasonal and geographic restrictions on the importation of fresh Hass avocados from approved orchards in Mexico to the United States. With the remaining systems approach compliance measures in place, pest risks do not substantially increase and U.S. net welfare rises by $77 million. Removal of remaining compliance measures may lead to lower net welfare gains depending on which measures are eliminated and the estimated probabilities of pest infestations.

Key words: avocados, compliance costs, NAFTA, SPS barriers, systems approach.

Technical barriers related to pest risks can block or significantly impede market access for agricultural products. One approach to easing these barriers is to shift from import bans to less restrictive instruments. Such opening of market access may be achieved through a systems approach to risk management, whereby a set of compliance procedures are specified that reduce the pest-risk externality associated with trade of a commodity. Adoption of systems approaches rest on 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).

This article develops a multi-season, partial equilibrium model with imperfect product substitution to evaluate the effects of allowing imports of fresh Hass avocados from approved orchards and packing houses in approved municipalities of Michoacán, Mexico, into the United States, under alternative compliance measures to mitigate pest risks. From 1914 until 1997, phytosanitary restrictions precluded entry of Mexican avocados into the conterminous United States due to prevalence of certain avocado-specific pests and fruit flies in Mexico. In November 1997, fresh Hass avocados from Mexico were allowed entry into nineteen northeastern states and the District of Columbia during a four-month period, November through February, under specified pest-management protocols. In 2001, the area approved for imports was expanded by an additional twelve states, and the period of importation was extended to six months, October 15 to April 15. The remaining geographic and seasonal restrictions were eliminated in a November 2004 rule that allowed year-around importation of Mexican avocados initially into forty-seven states (California, Florida, and Hawaii were excluded) and to all states starting in February 2007.

Progressive easing of the avocado import ban demonstrates successful application of a systems approach which has opened the U.S. market to approved Mexican producers and created more than a $100 million annual export industry. However, the compliance costs associated with the regulations remain controversial. Five avocado-specific pests generally not found in the United States (stem weevil, *Copturus aguacatae*; seed weevils *Conotrachelus aguacatae*, *C. perseae*, and *Heilipus lauri*; and seed moth, *Stenoma catenifer*) are prevalent within Mexico's production areas, particularly within noncommercial (backyard) orchards. Additional controversy has focused on four Mexican fruit flies (*Anastrepha fraterculus*, *A. ludens*, *A. serpentine*, and *A. striata*) that adversely affect numerous horticultural crops and are subject to local quarantine and

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We gratefully acknowledge funding by the USDA/ERS Program of Research on the Economics of Invasive Species Management (PREISM) and the Agricultural Development Policy Program of the Australian Centre for International Agricultural Research (ACIAR). We thank three anonymous reviewers for their suggestions and have benefited from discussions with many colleagues including Donna Roberts, Frank Filo, Claire Narrod, Suzanne Thornsbury, Eduardo Romano, Barry Krissoff, and Ray Trewin. Carlos Illsley and other growers and U.S. and Mexican phytosanitary officers in Urupan, Mexico graciously facilitated our field research.

Amer. J. Agr. Econ. 90(2) (May 2008): 321–335

DOI: 10.1111/j.1467-8276.2007.01121.x

eradication programs when discovered at U.S. sites. Mexican growers and sanitary authorities acknowledge the presence of the avocado pests but argue they can be effectively controlled in approved commercial orchards with relatively minimal measures, making the U.S. export compliance requirements excessive. They have also argued that Hass avocados are not a host for fruit flies, so the compliance measures required to monitor fruit fly infestations are unnecessary. USDA's Animal and Plant Health Inspection Service (USDA/APHIS) acknowledges that Hass avocados are a "poor" host for fruit flies but not a nonhost, which would justify elimination of the monitoring and control requirements.

The political economy of the controversy over avocado imports from Mexico has been intense. Roberts and Orden (1997) trace the regulatory process back through the 1970s, when Mexico nearly obtained import authorization, to the renewed discussions facilitated by the NAFTA negotiations in 1991, and the heated public hearings surrounding USDA's subsequent 1997 rule. Lamb (2006) further investigates the lobbying costs and political economy of this case in which the domestic industry once used full-page advertisements in major newspapers to assert that the Secretary of Agriculture by exposing it to pest risks was "about to destroy a $1 billion industry." Orden and Peterson (2006) conclude that opening of the U.S. market has required science (evidence of limited risk), opportunity (substantially higher prices in the U.S. market), traceability (to approved orchards), persistence (of the Mexican exporting association), and joint political will (under the NAFTA umbrella).

The economic impacts of avocado imports have been assessed in partial equilibrium simulation models in each of the final rules, but under the assumption that the systems approach adopted eliminated pest risks and without consideration of the exporter's compliance costs or potential trade-related pest damage. Romano (1998), and subsequently Orden, Narrod, and Glauber (2001), incorporate various pest risk and cost estimates into simulation of the 1997 partial opening of the market in a bilateral model with avocados from Mexico and the United States treated as perfect substitutes. Carman, Li, and Sexton (2006) present preliminary econometric evidence incorporating seasonality considerations to evaluate the implications of the initial market opening on likely imports with full Mexican access to the United States.

The analysis in this article extends the previous simulation analysis by explicitly considering compliance costs in Mexico, subsequent pest risks and U.S. producers' control costs and production losses in the event of a trade-related pest infestation. The analysis proceeds along lines suggested by Paarlberg and Lee (1998), Rendleman and Spinelli (1999), Glauber and Narrod (2001), Yue, Beghin, and Jensen (2006), Wilson and Anton (2006), and Calvin, Krissoff, and Foster (forthcoming) for determining optimal policies when there are pest risks associated with domestic or international movement of products. The model builds upon the detailed supply and demand structure utilized by APHIS in the economic analysis for the 2004 rule. The structural specification herein identifies three supply regions (southern California, Chile and Mexico), two seasons (winter and summer), and four domestic (U.S.) demand regions. In contrast to standard *ex ante* policy simulation analysis that uses demand and supply elasticities from the literature, our analysis utilizes post-2004-rule market data from 2005 to 2006 to calibrate and validate the model.

Three alternative compliance scenarios related to the ongoing controversies are examined in the simulation analysis: access to the U.S. market with the systems approach measures in effect as specified in the 2004 rule; additional elimination of the compliance measures directed specifically toward fruit flies; and elimination of all systems approach requirements. Our results show that the current systems approach reduces pest risk to a negligible level even without seasonal or geographic restrictions; fruit fly-related risks are minimal and eliminating the fruit fly compliance measures leads to a slight expected welfare gain; and elimination of all compliance measures for avocado-specific pests and fruit flies raises expected welfare under the average risk probabilities estimated by APHIS, but leads to a reduction of welfare compared to the 2004 rule under higher-risk probabilities. Because our model validation leads to a relatively large elasticity of avocado demand, we also undertake sensitivity analysis using two less-elastic values. The policy conclusions from a comparison among the three scenarios with the two levels of risk probabilities are robust across these alternative demand elasticities.

Framework of the Analysis

The avocado export program is administered jointly by APHIS and Mexico's Sanidad Vegetal (SV). The systems approach for importation of Mexican avocados contained nine different steps or requirements prior to the 2004 rule, as described in table 1. The 2004 rule eliminates the geographic and seasonal restrictions and modifies some of the remaining steps in light of the increased market access provided.

Only the Hass variety of avocados is included in the model because it accounts for nearly 85% of all avocados consumed in the United States. The chosen supply regions account for nearly all U.S. Hass avocado production (California) and over 95% of all Hass avocado imports (Chile and Mexico). The two seasons reflect seasonal production patterns among the suppliers and the restrictions on Hass avocado imports from Mexico prior to the 2004 rule. In season 1 (winter and a period of low domestic supply), Mexican Hass avocado imports were allowed into the specified states while no imports were allowed during season 2 (summer).

U.S. Consumer Demand

The demand for avocados is derived from a weakly separable, nested CES utility function for a representative consumer with purchases partitioned between avocados and everything else. Avocados from each of the three supply regions are assumed to be imperfect substitutes, reflecting observed U.S. wholesale price differentials. The demand specification for avocados in demand region *i*, from supply region *j*, in season *k* is defined as (see Keller 1976):

$$(1)\qquad q_{ij}^{k} = pop_i \left\{ \frac{b_{ki} a_{kij} wp_{kij}^{-\sigma_2} PI_{ki}^{(\sigma_2-\sigma_1)} I_{ki}}{b_{ki} PI_{ki}^{(1-\sigma_1)} + (1-b_{ki})} \right\}$$

where a_{kij} and b_{ki} are shift parameters, wp_{kij} is the wholesale price, σ_1 is the elasticity of substitution between avocados and all other goods, σ_2 is the elasticity of substitution among avocados, I_{ki} is per-capita income, and PI_{ki} is a CES price index defined as:

$$(2)\qquad PI_{ki} = \left\{ \sum_j a_{kij} wp_{kij}^{(1-\sigma_2)} \right\}^{\frac{1}{(1-\sigma_2)}}.$$

Four domestic demand regions are identified in the model to reflect differences in pest-risk susceptibility and per-capita consumption. Demand Region A corresponds to the thirty-one northern states and the District of Columbia, where imports of fresh Hass avocados were allowed by the 2001 rule. This region is not susceptible to outbreaks of any of the pests of concern. Southern California

Table 1. Systems Approach for Avocado Imports from Mexico

System Requirement	Description
Field surveys	Once per year prior to 2004, twice per year under 2004 rule
Trapping activities	1 trap per 10 hectares to monitor for fruit flies
Field sanitation	Remove fallen fruit weekly and prune dead branches
Host resistance	Hass cultivar only
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
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.
Port-of-arrival inspection	Inspectors ensure seals on the trucks are intact and shipment is accompanied by phytosanitary certification. One fruit per box from 30 boxes per shipment are sampled, cut, and inspect.
Geographical shipment restrictions	Shipments limited to 31 states plus District of Columbia (2001 rule); no geographic restrictions by February 2007 (2004 rule).
Seasonal shipment restrictions	Shipping allowed only October 15 to April 15 (2001 rule); no seasonal restrictions under 2004 rule.

Source: USDA/APHIS (2004b).

(Region D) 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. 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, the southwestern United States, northern California, and Hawaii. Region C is defined as a separate region due to its substantially larger per-capita consumption of Hass avocados than Region B.

The geographic area that is susceptible to fruit fly infestation is comprised of all of plant hardiness zones 8–11, which includes 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). Thus, only a portion of Regions B and C are susceptible to fruit fly infestation. 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 susceptible areas is proportional to the region's population in the those areas.

Supply of Californian Avocados

A Constant Elasticity of Transformation (CET) production possibilities frontier (Powell and Gruen 1968) is specified for California because ripe avocados may be left on the tree for many months before harvesting, allowing producers to shift sales between seasons as relative prices change. If a pest outbreak were to occur, the production possibilities frontier would shift inward toward the origin, as the pest outbreak reduces the amount of avocados produced from a given level of avocado specific factors (labor, capital and other inputs). A pest outbreak could also require producers to utilized costly control measures or affect the productivity of the inputs. The revenue function is:

$$(3)\quad R(p,V) = \left\{\delta(p_1 - CP)^{\beta} + (1-\delta)(p_2 - CP)^{\beta}\right\}^{\frac{1}{\beta}} \times [1 - (N_1 + N_2) pcteff * PL]V$$

where δ is a shift parameter, β is a parameter that determines the elasticity of transformation, p_1 and p_2 are producer prices in the first and second season, respectively, V is the level of factors employed, N_i is the frequency of a pest outbreak in season i, CP is expected per-unit cost of control measures, *pcteff* is the proportion of total acreage affected by an infestation, and PL is the proportion reduction in productivity caused by an infestation.

The expression $(N_1 + N_2) pcteff * PL$ is the expected annual pest-related productivity loss, whose value is restricted to range between 0 and 1 for positive revenue and outputs.[1] The frequency of a pest outbreak depends on the level of imports and will vary across seasons, while the proportion of acreage affected and reduction of productivity on this acreage determines the severity of the loss per outbreak. It is assumed that the productivity loss associated with an outbreak is the same regardless of the season in which it occurs. The expression $(p_i - CP)$ represents the expected net price received by producers after paying for any pest control measures.

The conditional supply functions are the derivatives of equation (3), with respect to the producer prices. As the risk of an outbreak increases, there are two effects on the expected supply in each season. First, the expected reduction in productivity lowers output in each season proportionally. Second, because the supply functions are conditional on the level of the avocado specific factor utilized, a decrease in the expected net producer price will also lead to a reduction in its utilization. A linear supply function is assumed for the level of the aggregate avocado specific factor, and its parameters are chosen to replicate the aggregate supply response for avocados in each supply region.

Frequency of Pest Outbreaks

The frequency (number) of pest outbreaks for each season (1, 2) and demand region is:

$$(4)\quad N = prob1 * prob2 * prob3 * prob4 * prob5 * suscept * Q^{E}_{mex}$$

where *prob*1 is the probability (on a per-pound basis) that a pest infects fruit pre- or post-harvest; *prob*2 that the pest is not detected during harvest or packing; *prob*3 that the pest survives shipment; *prob*4 that the pest is not

[1] As shown below, in our analysis the base values are 20% for PL and 3% for *pcteff*. At these values, it would take more than 166.67 pest outbreaks for the value of $(N_1 + N_2) pcteff * PL$ to exceed one, which is more than estimated in any of our simulations.

detected at port-of-entry inspection; *prob5* that an outbreak occurs if the pest is present; *suscept* is the proportion of the demand region that is susceptible to an infestation; and Q^E_{mex} is the quantity of avocados exported from Mexico to the region. For avocado-specific pests the value of *suscept* equals one for Region D and zero for all other regions. For fruit flies *suscept* equals 0.0, 0.553, 0.806, and 1.0 for Regions A, B, C, and D, respectively. Estimates of the individual probabilities for the cases of no risk mitigation measures implemented and for the systems approach were obtained from the pest-risk assessment undertaken by APHIS in preparation of the 1997 rule (USDA/APHIS 1996).

A range of probability values (minimum, average and maximum) were estimated by APHIS for fruit flies, stem weevils, seed weevils and seed moths.[2] Because of the uncertainty about the true probability values, our simulations are conducted using the estimated average and maximum values. Under the APHIS, average pest risk estimates the net probability of a fruit fly pest outbreak per pound of avocado imports ($prob1 * \cdots * prob5$) is 3.9E−10, with no pest-risk mitigation measures decreasing to 1.2E−13 under the systems approach; while at APHIS's maximum probability values, the corresponding net probabilities are 3.2E−9 and 1.2E−12, respectively. For stem weevils, which have the highest risk probabilities among the avocado-specific pests, under the APHIS average risk estimates the net probabilities are 3.9E−8 with no risk mitigation, decreasing to 2.7E−10 with compliance measures. With the high-risk estimates the net probabilities for stem weevils are 3.2E−7 and 2.3E−9, respectively.

Costs of U.S. Control Measures and Domestic Productivity Losses

Control cost and production losses are considered for avocados due to fruit flies and avocado-specific pests and for other horticultural crops due to fruit flies. For avocados, the expected annual per-unit cost of controlling fruit flies is expressed as:

$$(5) \qquad CP_{ff} = \frac{CP_{inf}(N_1 + N_2)}{y_1 + y_2}$$

where CP_{inf} is the estimated cost of control per outbreak based on an existing regulatory program, the Texas Valley Mexican Fruit Fly Protocol (USDA/APHIS 2000), and y_i is the quantity of avocados produced in season i. We utilize the upper estimate of costs per fruit fly outbreak ($500,000). There is no loss of fruit implying a zero productivity loss. For fruit fly infestations affecting other crops in susceptible areas of regions B, C and D, only the total cost of control per outbreak is utilized.

The potential cost of an infestation of an avocado-specific pest is based on estimates developed by Evangelou, Kemere, and Miller (1993). The general expression for expected annual average per-unit cost of control for avocado-specific pests over the two seasons is:

$$(6) \qquad CP_{ap} = \frac{Z * pcteff}{yield(1 - PL)} \frac{(N_1 y_1 + N_2 y_2)}{(y_1 + y_2)}$$

where Z is the cost per acre; *yield* is output per acre in the absence of pest infestation; and other terms are defined above. Evangelou, Kemere, and Miller estimated that the pesticide and labor costs required to control a weevil (or other avocado) pest infestation were $2,322 per affected acre. Also, an avocado-specific pest infestation was estimated to result in a 20% reduction in fruit production per acre. Based on an average yield of 6,548 pounds of avocados per acre in California during the 1993/1994 to 2003/2004 marketing years, the average cost is $0.443 per pound for the affected acreage.

The total cost of controlling a weevil or other avocado pest infestation also depends on the acreage affected. We follow USDA/APHIS (2000) and consider a mean of 3%. The costs are borne partly by public pest control agencies but in the model are fully reflected in prices received by avocado producers.

Mexican Avocado Supply and Compliance Costs

There are currently nearly 2,200 orchards in nine of the twenty-one municipalities of Michoacán that are approved to export to the United States. These orchards contained over 27,300 hectares in 2005. An average of 2.29 tons per hectare was harvested for export under the U.S. program out of average

[2] The full set of risk probabilities are reported in the Addendum I to Supplemental Risk Assessment (USDA/APHIS 1996). The November 2004 USDA/APHIS pest risk analysis provides only qualitative assessments of the economic impacts of each type of pest infestation.

total production per hectare of 9.7 tons (El Aguacatero).

The export supply of avocados from Mexico to the United States is also represented using a CET revenue function and linear supply function for the aggregate avocado specific factor utilized. Costs incurred by orchards to participate in the U.S. program include increased production costs to obtain export certification, fees paid to their local Junta de Sanidad Vegetal (JSLV) to cover avocado pest surveys and fruit fly trapping, and loss of fruit during field inspections.

The per-pound cost of compliance for Mexican avocado growers is specified as:

$$GCOST = \frac{[fieldc + pestsurv]ha + gfruit(p_1x_1 + p_2x_2)}{x_1 + x_2} \quad (7)$$

where *fieldc* is the cost per hectare of field sanitation; *pestsurv* is the cost per hectare of JSLV pest surveys; *ha* is the number of hectares in approved orchards; *gfruit* is the proportion of total exports cut and inspected in the field; p_i is the producer price of exported avocados in Mexico in season i; and x_i is the quantity of exports of avocados to the United States in season i. The number of hectares in approved orchards is kept constant at its 2005 level. Estimates of compliance costs under the 2001 and 2004 rules were obtained through field research (Orden and Peterson 2005). Field sanitation and pest surveys performed on the approved hectares regardless of the quantity of avocados exported are a fixed cost to the approved growers (estimated to be \$76.90 for field sanitation; \$76.67 for pest surveys under the 2001 rule and \$130.27 under the 2004 rule). The proportion of fruit inspected and cut in the field is 0.02.

The nearly 300 packing operations in Michoacán range from informal open sheds to modern enclosed facilities using machine sorting and cold storage. Costs for those exporters approved to participate in the U.S. program in 2005 include: investments to establish fruit fly quarantine conditions in their plants; operating costs of providing certification and protection from fruit flies during picking and processing; reimbursements for Mexican inspectors at the packing plants; and fees paid to reimburse APHIS inspection costs.

The per-pound cost of compliance for Mexican avocado exporters is specified as:

$$PCOST = pinvest + paphisv + \frac{inspect * plants + paphisf + pfruit * (p_1x_1 + p_2x_2)}{x_1 + x_2} \quad (8)$$

where *pinvest* is the estimated cost per pound of packing plant investment (\$0.005); *paphisv* is the variable cost portion of APHIS inspection costs (\$0.009 per pound); *inspect* is the cost of Mexican inspectors per plant (\$12,000); *plants* is the number of packing plants (22); *paphisf* is the fixed cost portion of APHIS inspection costs (\$335,940); and *pfruit* is the proportion of total exports cut and inspected in packing plants (0.004).

Benchmark Data

The initial equilibrium benchmark prices and quantities for the model are averages from the two-year period October 15, 2001 to October 15, 2003. Total consumption of fresh avocados in the United States (581.1 million pounds) is nearly evenly split between the two seasons.[3] California and Chile each provided about 40% of the avocados consumed during season 1, and Mexico provided about 20%. California avocados dominate U.S. consumption during season 2 (accounting for 75%). Wholesale prices of California avocados are substantially higher than prices of Chilean avocados in all demand regions in both seasons, while Chilean and Mexican avocado have similar wholesale prices in Region A during the first season.[4] Weighted average per pound wholesale prices across our four demand regions are \$1.476 during season 1 and \$1.696 during season 2 for Californian avocados, and \$1.176 during season 1 and \$1.413 during season 2 for Chilean avocados. Wholesale price differentials are also evident in Region A during season 1, where direct competition in

[3] Quantity of Californian Hass avocados shipped to each region is based on monthly shipment data from the Avocado Marketing Research and Information Center of the California Avocado Commission. Quantities of avocados imported from Chile and Mexico are taken from U.S. Census Bureau monthly data. Chilean imports are allocated to domestic demand regions proportional to Californian shipments.

[4] Wholesale prices are from Market News Archive, USDA Agricultural Marketing Service, Wholesale Market Fruit Reports (various issues). Producer prices for California avocados 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. from Orden and Peterson (2005).

the market has existed since 1997 (averaging $1.470, $1.10 and $1.080 for Californian, Chilean and Mexican avocados, respectively). Producer prices for Californian avocados were nearly $0.30 per pound higher than for Chilean and Mexican avocados in season 1 and nearly $0.50 per pound higher in season 2.

The marketing margins between producer and wholesale prices for each region in each season are derived by subtracting the producer prices from the wholesale prices. Because only one marketing margin is observed for Mexican avocados, that margin is used for all regions and seasons. The marketing margin for Mexican avocados includes the exporter costs of compliance with the systems approach. For the benchmark export volume the cost of compliance is calculated to be $0.081 per pound for growers (a relatively consequential 15% of producer price) and $0.026 per pound for exporters (5% of wholesale margin). 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 the exporter per-pound compliance costs.

Model Calibration and Validation

Because one year of market data is available after the 2004 rule, we use this post-reform data to choose the unknown parameters of and validate the model.[5] The elasticities of substitution in the nested CES utility functions and the supply elasticities for California and Chile are chosen such that after calibrating the model (selecting the shift parameters in [1] and [3]) to replicate the benchmark data, the model is able to closely replicate the observed quantities supplied and the average producer price for Californian avocados during November 2005 to October 2006.[6] The Mexican export supply is assumed to be very price-responsive (elasticity of 50) because less than one-quarter of the output from approved orchards is exported to the United States in the benchmark period. Because of limited substitution patterns, the elasticity of transformation in the CET revenue functions is set equal to 0.5 for all suppliers.

The calibration/validation procedure is more complicated than just implementing the elimination of the geographic and seasonal restrictions on Mexican avocado imports because other factors affect the observed market outcomes in the year to which the model is validated. Specifically, there is a substantially higher supply for California and lower supply from Chile in 2005/2006 than in our benchmark period. We interpret the large California supply as a weather-related positive shock, since acreage has been constant over the period from 1994/1995 to 2004/2005, and the 2005/2006 supply is 50% higher than average annual production during that period (California Avocado Commission). Similarly, Chilean avocado production and exports have been increasing since 2000, with nearly 90% of Chilean exports going to the United States (United Nations/FAO 2007). But there is a relatively low supply of avocados from Chile in 2005/2006, which we interpret as a negative supply shock. These shocks are modeled as shifts in the avocado specific factor supply functions during the validation simulation.[7]

The results of the calibration/validation procedure are shown in table 2. A very inelastic California supply, inelastic Chilean export supply and elastic U.S. demand (derived from the elasticities of substitution) were found to result in a close fit to the observed quantities and price. The implied demand elasticity is larger than estimated recently by Carman (2006). Less elastic demand results in too large of a price decline and too small of an increase in consumption in the calibration/validation compared with observed market outcomes. Thus, we believe the larger demand elasticities reasonably reflect recent consumer behavior for fresh avocados. Likewise, the observed market outcomes are only replicated with a quite inelastic California supply.

The main drawback to using this model validation approach is that with only one year of data, it may be possible that multiple combinations of parameter values "fit" the observation. We find that under the proposition that the supply of Californian avocados is very inelastic, as shown by Carman and Craft (1998), and that the export supply of avocados from Mexico is very elastic, given their excess capacity

[5] We thank an anonymous reviewer for directing us to this calibration and validation approach.

[6] Data for 2005/2006 avocado marketing year is obtained from the Avocado Marketing Research and Information Center.

[7] The geographic restrictions that still limited Mexican avocados to forty-seven states in 2005/2006 are modeled by excluding exports to Region D. This provides only an approximation of the geographic restrictions that were in effect since our other demand regions include northern California, Florida, and Hawaii. Without re-specifying the model's demand structure, we could not fully address this discrepancy. The calibration/validation also accounts for population and income growth subsequent to the benchmark period.

Table 2. Model Calibration and Validation

		Outcomes	
Parameter	Value	Nov 2005 to Oct 2006	Calibration/Validation
Elasticities of substitution			
σ_1	1.75		
σ_2	2.75		
Aggregate demand *(for California avocados)*	−2.06		
Aggregate supply		Million Pounds	
California	0.05	557.2	558.9
Chile	0.50	126.4	132.8
Mexico	50.0	251.3	226.5
Total		934.9	918.2
		Dollars Per Pound	
Producer price *(annual weighted average for California avocados)*		$0.577	$0.601

Data for 2005/2006 avocado marketing year is obtained from the Avocado Marketing Research and Information Center.

to provide avocados to the United States under the system approach, it greatly restricts the possible values of the demand elasticities that would validate the model.

Modeling the Removal of Import Restrictions

Simulating the removal of seasonal and geographic import restrictions for Mexican avocados for the model calibration/validation or the subsequent policy scenarios requires that shift parameters of the CES utility function be adjusted from initial zero values, which were used to match the absence of consumption from Mexico in the benchmark period (Region A in season 2 and for Regions B, C, and D in both seasons). Following Venables's (1987) analysis of trade policy effects on differentiated products, we assume that these demand shift parameter values for avocados from Mexico can be set equal to the shift parameter values for Chilean avocados after the change in import restrictions. In Regions B, C, and D during season 1, the shift parameters for California avocados are set equal to 0.4, and the shift parameters for Chilean and Mexican avocados are both set equal to 0.3. This maintains the initial preference bias for California avocados as indicated in the calibrated value of the initial shift parameters of approximately 0.6 for Californian avocados and 0.4 for Chilean avocados.

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, and the preference parameter for California avocados is decreased by the same amount (to preserve summation of the coefficients to one for each demand region in each season). The initial shift parameters for avocados from Chile during season 2 are smaller in value than for season 1 (e.g., in Region A the initial value in season 2 is 0.1756). A larger preference bias 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.

In the supply specification the parameter δ equals 1 initially for Mexico because no avocados are allowed to be exported during season 2. In the simulations δ is set equal to 0.6 to match the proportion of Mexico's total worldwide exports during season 1.

Simulation Results

Because the supply shocks accounted for in the calibration/validation are likely to be transitory, we use the benchmark data as a starting point for the policy simulations. The simulation outcomes are not expected to match the observed outcomes for 2005/2006, but to give an assessment of the effect of only the policy change assuming access for Mexican avocados to all fifty states.

In the first scenario the geographic and seasonal restrictions on avocado imports from Mexico are eliminated while maintaining the other compliance measures of the systems approach. This corresponds to implementation of the 2004 rule. In the second scenario the geographic and season restrictions are eliminated

Table 3. Frequency of Pest Outbreaks

	Risk Probability Levels					
	Scenario 1[a]		Scenario 2		Scenario 3	
Frequency of Outbreak	Average	High	Average	High	Average	High
Fruit flies						
Season 1: Region B	1.0E−6	1.0E−5	2.3E−4	2.0E−3	3.6E−3	3.0E−2
Region C	5.0E−6	4.8E−5	1.2E−3	9.8E−3	1.8E−2	1.5E−1
Region D	3.0E−6	2.5E−5	5.9E−4	5.0E−3	9.3E−3	7.8E−2
Season 2: Region B	1.0E−6	7.0E−6	1.8E−4	1.5E−3	2.7E−3	2.3E−2
Region C	4.0E−6	4.1E−5	9.8E−4	8.3E−3	1.5E−2	1.3E−1
Region D	3.0E−6	2.5E−5	6.0E−4	5.1E−3	9.4E−3	7.9E−2
Stem Weevil: Season 1	5.9E−3	4.9E−2	6.0E−3	5.0E−2	9.3E−1	7.8
Season 2	6.0E−3	5.0E−2	6.1E−3	5.1E−2	9.4E−1	7.9
Seed Weevil: Season 1	2.3E−5	2.2E−4	2.4E−5	2.2E−4	7.6E−3	6.9E−2
Season 2	2.3E−5	2.2E−4	2.4E−5	2.2E−4	7.6E−3	7.0E−2
Seed Moth: Season 1	1.0E−6	7.0E−6	1.0E−6	7.0E−6	2.2E−3	2.2E−2
Season 1	1.0E−6	7.0E−6	1.0E−6	7.0E−6	2.2E−3	2.2E−2

[a]Scenario 1 is unlimited seasonal and geographic access with existing compliance measures; Scenario 2 is unlimited access without fruit fly compliance measures; Scenario 3 is unlimited access without all compliance measures.

along with fruit fly monitoring of orchards and quarantine requirements during harvests and packing in Mexico. This is assumed to raise the probability of a fruit fly infestation during pre- or post-harvest (*prob1* in equation 2) from its system approach level (2.5E−06) to its level without the risk mitigation measures (5.5E−04). 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. In the third scenario all compliance measures that have been applied to avocado imports from Mexico are removed. The risk probabilities are assumed in the third scenario to be at their levels estimated by APHIS with no risk mitigation measures.

Pest Outbreak Frequencies and U.S. Control Costs

The frequencies of expected pest outbreaks are shown in table 3 for the three scenarios. For fruit flies the frequency of an outbreak is very low, less than 5.0E−6 per year, under the average risk probabilities in scenario 1.[8] The frequency increases in scenario 1 by an order of magnitude (to at most 4.8E−5) under the high-risk probabilities. Eliminating the compliance measures specific to fruit flies in Mexico raises the frequency of outbreaks in the U.S. by two orders of magnitude, and eliminating all of the system approach pest control compliance measures raises these risks another order of magnitude. The maximum estimated frequency of a fruit fly outbreak reaches 0.15 in Region C during season 1 in scenario 3. For southern California (Region D) the expected cost of controlling the fruit fly outbreaks never exceeds $0.00024 per pound (in scenario 3, not shown in the tables) when averaged over the quantity of avocados produced. The total cost of fruit fly controls for expected outbreaks in Regions B and C due to importing avocados from Mexico remain low (at most $244,000 for the worst case of high pest-risk probabilities in scenario 3, as shown in table 4).

The expected frequencies are low for outbreaks of avocado-specific pests due to imports from Mexico in scenario 1. Among the avocado pests, stem weevils have the highest frequency of an outbreak by two orders of magnitude. The avocado pest frequencies are not affected directly by removing the fruit fly compliance measures in scenario 2.[9] But in scenario 3, the avocado pest outbreak frequencies rise by two or more orders of magnitude. For stem weevils expected frequency of an outbreak reaches approximately 0.93 per season under the average pest-risk probabilities and 7.8 per season under the high pest-risk probabilities. The

[8] Region C has a higher frequency of fruit fly outbreaks the Region D due to a larger population.

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

Table 4. Simulated Outcomes for the Three Policy Scenarios

		Simulation Outcomes					
		Scenario 1		Scenario 2		Scenario 3	
	Base Values	Average Risk	High Risk	Average Risk	High Risk	Average Risk	High Risk
Producer prices				Dollars Per Pound			
Season 1: California	0.871	0.666	0.666	0.664	0.664	0.662	0.695
Chile	0.577	0.452	0.452	0.451	0.451	0.447	0.450
Mexico	0.540	0.489	0.489	0.485	0.485	0.462	0.461
Season 2: California	1.101	0.871	0.871	0.870	0.870	0.868	0.901
Chile	0.599	0.537	0.538	0.537	0.537	0.534	0.539
Mexico	0.540	0.570	0.570	0.566	0.566	0.543	0.544
Wholesale price *(weighted annual average)*							
California	1.622	1.400	1.400	1.398	1.398	1.397	1.430
Chile	1.268	1.168	1.168	1.167	1.166	1.163	1.167
Mexico	1.080	1.056	1.056	1.046	1.046	1.010	1.010
Quantities supplied *(annual)*				Million Pounds			
Total	581.071	763.865	763.785	768.710	768.629	787.370	774.863
California	346.011	341.937	341.839	341.905	341.804	339.682	324.142
Chile	176.813	161.505	161.508	161.359	161.363	160.835	161.350
Mexico	58.247	260.423	260.438	265.446	265.462	286.853	289.371
Mexican compliance cost				Million Dollars *(dollars per pound)*			
Growers	4.726	8.291	8.291	7.097	7.097	0.000	0.000
	(0.081)	*(0.032)*	*(0.032)*	*(0.027)*	*(0.027)*		
Shippers	1.541	4.791	4.791	3.540	3.540	0.000	0.000
	(0.026)	*(0.018)*	*(0.018)*	*(0.013)*	*(0.013)*		
California cost of control	0.000	0.027	0.228	0.028	0.237	4.274	34.276
		(7.9E−5)	*(6.7E−4)*	*(8.2E−5)*	*(7.0E−4)*	*(0.013)*	*(0.106)*
Welfare effects							
Producer surplus							
California		−76.269	−76.401	−76.763	−76.902	−81.586	−102.127
Chile		−16.848	−16.844	−17.002	−16.998	−17.551	−16.998
Mexico		5.093	5.094	5.302	5.302	6.236	6.351
U.S. equivalent variation		153.721	153.646	156.915	156.836	168.441	156.441
Other fruit fly costs		8.0E−06	7.8E−05	0.002	0.016	0.029	0.244
Net U.S. welfare change		77.452	77.245	80.150	79.918	86.826	54.069

expected frequencies of other avocado pest outbreaks remain two orders of magnitude smaller.

When the system approach compliance measures are all removed in scenario 3, the expected costs of control measures born by California orchards become substantial, particularly for the relatively frequent outbreaks of stem weevil. These costs are estimated to be \$0.012 per pound of California production at the average risk probabilities. At the high-risk probabilities the seed weevil-related costs and losses reach \$0.106 per pound in scenario 3. Thus, terminating all systems approach compliance measures with high pest risks places onto the domestic U.S. industry pest control costs on the same order of magnitude per pound of California avocado sales as the costs borne by Mexican producers and exporters per pound of exports under the 2001 rule.

Market Equilibrium and Welfare Changes

Because Mexican avocados become more available and are relatively less expensive than other avocados in scenario 1, there is a decline in demand for avocados from California and Chile. With the relatively inelastic supply of Californian and Chilean avocados, the drop in demand leads to lower producer and wholesale prices, with only inconsequential differences in the outcomes with average versus high pest-risk probabilities. As shown in table 4, which provides a summary of the results, producer prices for California and Chilean avocados decline in the range of 10–25% in each season (more in season 1 than season 2), and wholesale prices decline by 5–15%. The annual equilibrium quantity demanded and supplied falls by 1.2% for California avocados and by 8.7% for avocados from Chile.[10]

With the increased seasonal and geographic access allowed under scenario 1, annual exports from Mexico increase by 345%, from 58.2 million pounds to 260.4 million pounds. Although increased requirements raise the total compliance costs from $6.3 million to $13.1 million with year-round shipping, the increase in exports lowers the per-pound costs in Mexico to $0.032 for growers and $0.018 for exporters (table 4). These per-pound compliance costs are only 39.5% and 69.2%, respectively, of the benchmark levels. The reduction in compliance costs affects both the net price received by Mexican growers (gross [market] producer price less compliance costs) and the marketing margin on Mexican avocados. The net producer price remains virtually unchanged in season 1, even though the gross price falls by 9.4%. The decline in the gross price in season 1 is due to both supply and demand factors. On the supply side season 1 is the peak of Mexican avocado production and exports, and with a low elasticity of transformation, there is limited ability for Mexican growers to shift exports between seasons. On the demand side, because Mexico had market access in Region A initially, the increase in market access is smaller in season 1 as compared with season 2, where there was no initial market access. In season 2 the larger increase in market access as well as lower seasonal production in Mexico increases the gross and net prices by 5.6% and 7.5%, respectively. The reduction of marketing margins due to the decrease in compliance costs for Mexican exporters translates into a 13.8% larger reduction in the wholesale price of Mexican avocados in season 1 than otherwise and a 25.7% smaller increase in the wholesale price in season 2.

The expected producer surplus for California avocado growers declines by $76.3 million in scenario 1 ($76.4 million for high risks). This decrease reflects the impact of expanded trade and the small effects from expected control costs and losses in output due to pest damage. Expected pest control cost to California avocado growers due to imports from Mexico is only $27,000 with average pest risks and $228,000 with high risks. Pest control costs for fruit flies for other U.S. crops are negligible. Producer surplus also declines by $16.8 million for Chilean avocado growers but increases by $5.1 million for Mexican growers. The relatively small increase in Mexican producer surplus reflects the elastic export supply, which implies that most of the benefits of the policy change are passed on to U.S. consumers. Total U.S. avocado consumption increases from 581.1 million pounds to 763.9 million pounds. The total estimated gain in equivalent variation for U.S. consumers is $153.7 million ($153.6 million for high risks). Net welfare in the U.S. increases by $77.5 million ($77.2 million for high risks).

Eliminating fruit fly monitoring would reduce the field survey costs from $130.27 per hectare in scenario 1 to $85.58 per hectare in scenario 2. This translates into approximately a $0.005 per pound reduction in growers' compliance costs, with shipper compliance costs reduced by an equivalent amount from the elimination of plant quarantine requirements for fruit flies. With the decrease in grower compliance costs, the average annual net price received by Mexican producers increases by $0.001 per pound (0.17% compared to scenario 1), which leads to an increase in Mexican avocado exports by 5.0 million pounds (an 8.6% larger increase in exports compared to the benchmark than in scenario 1).

The average annual wholesale price of Mexican avocados in the United States falls $0.009 per pound (0.8%) as compared with scenario 1. This small reduction, relative to the wholesale prices of Californian and Chilean avocados, leads to only very small changes in equilibrium quantities demanded of Californian and Chilean avocados compared to scenario 1 (32,000 and 146,000 pounds respectively). This small change in quantity demanded is accompanied by a small reduction in producer prices of Californian and Chilean avocado of $0.001 per pound.

Most of the welfare benefits of eliminating fruit fly monitoring accrue to U.S. consumers, who gain an additional $3.2 million in equivalent variation compared to scenario 1. Producer surplus for Californian and Chilean growers declines by about $500,000 and $155,000, respectively, while producer surplus for Mexican growers increases by about $210,000 (for both average or high-risk probabilities). The expected pest control costs in the U.S. remains low at $28,000, with average pest risks and $237,000 with high risks. Net U.S.

[10] A complete set of results is available from the authors upon request.

welfare increases by approximately $2.7 million compared to scenario 1 under either average or high risks.

In the third scenario, there are no compliance costs in Mexico, but trade-related pest infestations become frequent enough that expected control cost for California avocado growers increase significantly to $4.3 million with average pest risks.[11] The increase in control costs leads to a reduction in the annual average net price received by California growers of $0.015 per pound compared to scenario 1. In addition the expected infestations of avocado-specific pests lead to a 1.1% productivity loss with average pest risks. With the decrease in the net price and the productivity loss, Californian avocado production falls by 2.3 million pounds as compared with scenario 1. The reduction in Californian producer surplus is about $5 million higher than in scenarios 1 and 2.

Because of the very elastic Mexican export supply, most of the benefits of the elimination of all compliance measures in Mexico are passed on to U.S. consumers. Compared with scenario 1, total compliance costs are reduced by $0.05 per pound. Mexican growers receive a $0.005 per pound increase in their net price, and Mexican exports increase by 26.4 million pounds compared to scenario 1. The gross producer price of Mexican avocados falls by $0.027 per pound. With the reduction in the gross price and exporter compliance costs, the wholesale price of Mexican avocados declines by $0.046 per pound compared to scenario 1.

For average pest risks, the U.S. net gain in welfare is $86.8 million, a gain of $6.7 million and $9.4 million compared to scenarios 2 and 1, respectively. The equivalent variation for U.S. consumers is $168.4 million in scenario 3 with average risks—$11.5 million and $14.7 million higher than for scenarios 2 and 1. Thus, there is an additional domestic welfare gain associated with eliminating all of the system approach compliance measures at the average pest risks estimated by APHIS, in spite of the significant pest-related losses to California avocado growers.

Unlike scenarios 1 and 2, where the use of average or high pest-risk probabilities had little effect on the model results, for scenario 3 there are quite different results under high pest risks. The nearly hundred-fold increase in the expected frequency of stem weevil outbreaks increases the cost of control for California growers to $34.3 million and the trade-related productivity loss from pest infestations to 9.5%. These two effects lead to the equilibrium quantity supplied of California avocados falling by 15.5 million pounds as compared with scenario 3 with average pest risks. This reduction in the equilibrium quantity supplied results in a $0.033 per pound higher wholesale price of Californian avocados as compared with the average pest-risk case. Total avocado consumption falls by 12.5 million pounds as compared with the case with average pest risks, even with the fairly large elasticities of substitution in consumption.

The higher control costs and productivity losses lead to a $20.5 million larger decrease in producer surplus for California growers as compared with scenario 3 with average pest risks. In addition the reduction in avocado consumption results in a $12.0 million lower gain in U.S. consumer equivalent variation, with a slight decline even with higher imports, as compared with scenario 2. The net U.S. welfare gain of $54.1 million in scenario 3 under high pest-risk probabilities is less than the net gains in scenarios 1 or 2 under either average or high-risk probabilities. Thus, it is possible that removing all of the system approach measures for Mexican avocados could lead to a lower net welfare gain than only removing the seasonal and geographic restrictions or these restriction plus the fruit fly monitoring requirements.[12]

Sensitivity Analysis

Sensitivity analyses are conducted to investigate the effects of uncertainty in our estimates of the underlying costs of compliance (for scenarios 1 and 2) and control costs and losses (for all three scenarios) and uncertainty in the supply and demand elasticities. For the costs of compliance, we focus on the two costs with the most uncertainty: costs of field sanitation and packinghouse quarantine. A range of plus and minus 20% above our initial cost estimate is used for field sanitation costs and plus and minus 50% for the cost of packinghouse quarantine. For California control costs

[11] The costs of controlling fruit fly outbreak remain low in scenario 3, regardless of the pest risk probabilities used.

[12] Yue, Beghin, and Jensen (2006) also note the possibility of consumer welfare falling with expanded trade when domestic and imported goods are imperfect substitutes, and trade-related pest outbreaks occur. Orden, Narrod, and Glauber (2001) called attention to this possibility in the case of limited trade but with homogeneous products and perfectly elastic Mexican supply did not find adverse effects on consumers with full market access.

Table 5. Comparison of U.S. Welfare Estimates Across Alternative Demand Elasticity Values

	Simulation Outcomes					
	Scenario 1		Scenario 2		Scenario 3	
Elasticity Estimates[a]	Average Risk	High Risk	Average Risk	High Risk	Average Risk	High Risk
Net U.S. welfare change			Million Dollars			
Carman (−0.4)	71.016	70.859	73.686	73.519	81.395	57.594
APHIS (−0.98)	75.329	75.158	78.036	77.848	85.465	58.669
Validation (−2.06)	77.452	77.245	80.149	79.918	86.826	54.069
California producer surplus						
Carman (−0.4)	−241.951	−241.990	−243.305	−243.347	−249.604	−254.920
APHIS (−0.98)	−144.914	−144.993	−146.003	−146.087	−152.052	−164.027
Validation (−2.06)	−76.269	−76.401	−76.763	−76.902	−81.586	−102.127
U.S. Equivalent variation						
Carman (−0.4)	312.968	312.849	316.992	316.876	331.016	312.660
APHIS (−0.98)	220.244	220.151	224.041	223.947	237.538	222.878
Validation (−2.06)	153.721	153.646	156.914	156.837	168.441	156.441

[a] Alternative demand elasticity estimates obtained from Carman (2006), USDA/APHIS (2004a), and model validation procedure. Values in parentheses are aggregate demand elasticity for California avocados.

and productivity losses, the following are considered: a range of plus and minus 10% for the average avocado yield per acre; a range from 1 to 5% for the acreage affected by each outbreak (plus or minus 2%); and a range of 10–30% for the productivity loss for each outbreak of an avocado-specific pest (plus or minus 10%). Each uncertain parameter is assumed to have an independent uniform distribution, and the sensitivity analysis uses symmetric order three Gaussian quadratures. Arndt and Hertel (1997) have shown that sensitivity analyses conducted using order three quadratures are as accurate as higher order quadratures.

In general, the model results are not sensitive to alternative assumptions about compliance and control costs. For scenarios 1 and 2, with average or high pest risks, the standard deviations for Californian producer surplus, U.S. consumer equivalent variation and net U.S. welfare gains are approximately $0.2 million, $1.1 million and $1.0 million, respectively. As the frequency of pest outbreak increases in scenario 3, the amount of acreage affected per outbreak and the level of productivity loss associated with each outbreak become more important. For average pest risks the standard deviations of the three U.S. welfare measures increase slightly to $1.1 million, $0.8 million and $1.8 million, respectively. Because the frequency of infestation increases by an order of magnitude for high pest risks, the standard deviations increase, respectively, to $9.3 million, $6.7 million and $14.9 million.

Because the aggregate demand elasticity for California avocados obtained from the validation procedure is quite large, we considered two alternative less-elastic specifications of aggregate demand to determine the robustness of the model results.[13] The alternative aggregate demand elasticities are based on recent econometric estimates by Carman (−0.4) and the elasticity utilized in the APHIS economic assessment (−0.98). All scenarios are re-run using these alternative demand elasticities, holding all other parameter values constant.

As shown in table 5, net U.S. welfare gains are smaller with less elastic demand, but the range of estimates does not vary much across the different values. There is substantial variation in producer surplus for California avocado growers and in U.S. equivalent variation. As demand becomes more inelastic, with an inelastic supply of avocados from California, there are larger reductions in prices received by California avocado growers. This leads to larger decreases in producer surplus. However, as long as the producer price decreases are passed onto consumers, as is assumed in the model, then U.S. consumers gain additional benefit from the lower prices of Californian avocados. These two effects nearly offset each other. More inelastic demand also reduces the pest-risk-related losses because the level of

[13] We thank one anonymous reviewer for emphasizing sensitivity to the demand elasticity.

exports from Mexico is substantially reduced.[14] Thus, while the alternative demand elasticities affect the distribution of gains and losses, our estimates of pest-risk losses and net U.S. welfare gains across the three policy scenarios are robust to a wide range of demand elasticity values.

Conclusion

A long and contentious dispute between Mexico and the United States over restrictions on importation of Hass avocados has been largely resolved since 1997, by replacing an import ban with trade under a systems approach of mitigation measures designed to reduce fruit fly and avocado-specific pest risks. This article has developed a model to evaluate the effects of fresh Hass avocado imports from Mexico under alternative systems approach measures. We find that eliminating geographic and seasonal restrictions under the November 2004 rule substantially expands trade and lowers Mexican per-unit compliance costs. Pest risks remain low with the other compliance measures still in place. The estimated annual net U.S. welfare gain from eliminating all geographic and seasonal restrictions is approximately $77.4 million. Thus, the benefits from the decision made by USDA in 2004 to allow imports of Mexican avocados without geographic or seasonal restrictions under a systems approach are confirmed when pest risks and related costs are incorporated into the analysis.

Analysis of alternative avocado import pest-risk management policies that eliminate some or all of the remaining compliance measures suggests two additional conclusions. First, the additional U.S. welfare gains from further modification of the systems approach to eliminate fruit fly control measures are modest. Second, entirely abandoning the systems approach would be a questionable decision on pest-risk and economic criteria. This is because our knowledge of the magnitudes of the pest-risk probabilities is not sufficient to rule out a smaller U.S. welfare gain compared to when some or all of the system approach compliance measures are retained. These conclusions hold up over a wide range of alternative demand elasticity assumptions.

[Received June 27, 2006; accepted September 20, 2007.]

[14] Pest-related costs are not shown separately in table 5. The complete set of results is available on request.

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