Linking Risk and Economic Assessments in the Analysis of Plant Pest Regulations:
The Case of U.S. Imports of Mexican Avocados

Everett Peterson and David Orden*

Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 23-26, 2006

* Everett Peterson (petrsone@vt.edu) is Associate Professor, Department of Agricultural and Applied Economics, Virginia Tech. David Orden (d.orden@cgiar.org) is Professor, Department of Agricultural and Applied Economics, Virginia Tech and Senior Research Fellow, Markets, Trade and Institutions Division, International Food Policy Research Institute (IFPRI). A presentation of this material was also made at the IATRC symposium, "Food Regulation and Trade: Institutional Framework, Concepts of Analysis and Empirical Evidence," Bonn, Germany, May 28-30, 2006.

This paper was prepared for the USDA, Economic Research Service, Program of Research on the Economics of Invasive Species Management (PREISM) through a grant to Virginia Polytechnic Institute and State University (Virginia Tech). We thank ERS for financial support. We have benefited from discussions with our ERS project collaborators and other colleagues, including Suzanne Thorsnbury, Eduardo Romano, Claire Narrod, Joe Glauber, Trang Vo, Barry Krissoff, Donna Roberts, Ben Faber, and Ray Trewin. We have also benefited from interaction with Frank Filo and other staff of the USDA Animal and Plant Health Inspection Service (APHIS) with whom we collaborated to prepare the economic analysis for a November 2004 USDA rule that rescinded previous seasonal and geographic restrictions on access of Mexican Hass avocados to the United States. Additional financial support for development of the modeling framework to incorporate pest risks and related costs into economic equilibrium assessments under alternative compliance measures has been provided by the Australian Centre for International Agricultural Research (ACIAR) through a grant to the International Food Policy Research Institute (IFPRI).

Our field research in Mexico to evaluate compliance costs associated with the pest risk mitigation measures required for avocado exports to the U.S. was graciously facilitated by Carlos Illsley, Alberto Cisneros and other growers, packers and U.S. and Mexican sanitary inspection personnel in and around Urupan, Michoacán. Dale McNiel and Ron Campbell in Washington D.C. helped make the arrangements for the field research.

Corresponding Author:

David Orden
Markets, Trade and Institutions Division
International Food Policy Research Institute
2033 K Street, N.W.
Washington D.C. 20006

Phone: (202) 862-8160

Linking Risk and Economic Assessments in the Analysis of Plant Pest Regulations: The Case of U.S. Imports of Mexican Avocados

1 Introduction

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 paper develops a static, multi-season, partial equilibrium model to evaluate the economic 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 in Mexico of certain avocado-specific pests and fruit flies. In November 1997, fresh Hass avocados from Mexico were allowed entry into 19 northeastern states and the District of Columbia during a four-month period, November through February, under approved pest-management protocols. In 2001, the area approved for imports was expanded by an additional 12 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 allows year-around importation of Mexican avocados into all states by 2007.[1]

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 a $100 million export industry. However, the compliance costs associated with the regulations remain controversial. Mexican growers and sanitary authorities have argued that avocados are not a host for fruit flies, so compliance measures required to monitor fruit fly infestations are unnecessary, and that compliance requirements for the avocado pests (seed and stem weevils and seed moths) are excessive. USDS's Animal and Plant Health Inspection Service USDA/APHIS) acknowledges that avocados are a "poor"

[1] Mexico had nearly gained access to the U.S. market in the 1970s but failed until the NAFTA negotiations provided a new forum for discussions between the two countries. See Roberts and Orden (1997) and Orden and Peterson (2006) for discussion of the political economy of this long regulatory reform process.

host for fruit flies. But its economic assessment for the 2004 rule did not examine Mexican compliance costs and assumed zero pest risk.

The avocado analysis is extended in this paper to explicitly consider pest risks, compliance costs in Mexico, 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 Glauber and Narrod (2005), Rendleman and Spinelli (1999) and Paarlberg and Lee (1998) for determining optimal policies when there are pest risks associated with domestic or international movement of products. The avocado model identifies three supply regions (southern California, Chile and Mexico), two seasons (winter and summer), and four domestic (U.S.) demand regions, with avocados from different sources assumed to be heterogeneous goods. Three alternative compliance scenarios are examined: access to the U.S. market with the systems approach measures in effect as specified in the 2004 rule, further removal of the compliance measures directed specifically toward fruit flies, and elimination of all systems approach requirements.

2 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 percent of all avocados consumed in the United States. The supply regions chosen account for nearly all U.S. Hass avocado production (California) and over 95 percent of all Hass avocado imports (Chile and Mexico). The two time periods reflect the seasonal restrictions on Hass avocado imports from Mexico prior to the 2004 rule. During period 1 (winter) Hass avocado imports were allowed into the specified states. Period 2 (summer) is defined as April 16-October 14 when Hass avocado imports were not allowed from Mexico.

2.1 U.S. Consumer Demand

The demand for avocados is derived from a weakly separable 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 persistent wholesale price differentials observed in the United States.

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 31 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 (Region D) is identified as a separate 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 U.S. is disaggregated into two regions: Region B, which is defined as the southeastern U.S., and Region C, which is defined as the Pacific Northwest, the southwestern U.S., 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 defined as all of plant hardiness zones 8-11 in the U.S., 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). 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 that lives in the those areas.

2.2 Supply of Californian Avocados

A Constant Elasticity of Transformation (CET) production possibilities frontier is specified for California because ripe avocados may be left on the tree for many months before harvesting, allowing producers to shift sales between time periods as relative prices change. If a pest outbreak were to occur, the production possibilities frontier would shift inward towards 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 specified as:

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

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 time period, V is the level of factors employed, N_i is the frequency of a pest outbreak in time period i, CP is expected per-unit cost of control measures, and PL is the percent reduction in productivity caused by an infestation.

The expression $\left[1-\left(N_1+N_2\right)PL\right]$ is the expected annual pest-related productivity loss. 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 which time period it occurs. 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 the derivatives of equation (1) with respect to the producer prices. As the risk of an outbreak increases, there are several effects on the expected supply in each time period. First, the expected reduction in productivity reduces production in each time period proportionally. Second, differences in the frequency of an outbreak will lead to differences in the expected control costs and therefore differences in the net expected price, which will lead to shifts in production between time periods. Finally, 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 vocado specific factor.

2.3 Frequency of Pest Outbreaks

The frequency (number) of pest outbreaks for each time period (1, 2) and demand region (B-D for fruit flies and D only for avocado pests) is determined as:

(2)
$$N = prob1 * prob2 * prob3 * prob4 * prob5 * Q_{mex}^{E}$$

where $prob1$ is the probability (on a per-pound basis) that a pest infects fruit pre- or post-harvest, $prob2$ that the pest is not detected during harvest or packing, $prob3$ that the pest survives shipment, $prob4$ that the pest is not detected at port-of-entry inspection, and $prob5$ that the pest is able to become established. Q_{mex}^{E} is the quantity of avocados exported from Mexico to the region. Estimates of the individual probabilities in the case of no specific risk mitigation measures implemented and under the systems approach to risk mitigation were obtained from the pest risk assessment undertaken by APHIS in preparation of the 1997 rule (USDA/APHIS, 1996).[2] Probability values were estimated by APHIS for fruit flies, seed weevils, stem weevils, and seed moths.[3] Because the true probability values are unknown, simulations are conducted using the estimated average and maximum values.

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

The expected annual per-unit cost of controlling fruit flies in avocado-producing Region D is expressed as:

(3)
$$CP_{ff} = \frac{CP_{inf}\left(N_1 + N_2\right)}{y_1 + y_2}.$$

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

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

[3] Fruit flies applies to *Anastrepha fraterculus*, *A. ludens*, *A. serpentine*, and *A. striata*; seed weevil refers to *Conotrachelus aguacatae*, *C. perseae*, and *Heilipus lauri*; stem weevil refers to *copturus aguacatae*; seed moth refers to *Stenoma catenifer*.

produced in period *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 crops in susceptible areas of regions B and C only a total cost of control per outbreak is estimated.

The potential cost of an infestation of an avocado-specific pest is based on estimates developed by Evangelou, *et al.* (USDA/APHIS, 1993). They estimated that the pesticide and labor costs required to control a weevil (or other avocado) pest infestation was $2,322 per acre. Also, an avocado-specific pest infestation was estimated to result in a 20 percent reduction in fruit production per acre. Based on an average yield of 6,548 pounds of avocados per acre in California during the 1993/94 to 2003/04 marketing years, the average cost is $0.443 per pound.

The total cost of controlling a weevil or other avocado pest infestation depends on the acreage affected. We follow USDA/APHIS (2000) and consider a range of different infestation rates ranging from one percent to five percent, with a mean of three percent.[4] The expected annual average per-unit cost of control for avocado-specific pests over the two time periods is:

(4)
$$CP_{ap} = \frac{Z * pcteff}{yield\left(1-PL\right)} \frac{\left(N_1 y_1 + N_2 y_2\right)}{\left(y_1 + y_2\right)}.$$

where Z is the cost per acre, *pcteff* is the percentage of total acreage affected by an infestation, *yield* is output per acre in the absence of pest infestation, and other terms are as defined above. These costs are borne partly by public pest control agencies but in the model are fully reflected in prices received by avocado producers.

2.5 Mexican Avocado Supply and Compliance Costs

There are currently nearly 2,200 orchards in nine of the 21 municipalities of Michoacán that are approved to export to the U.S. 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 total production per hectare of 9.7 tons.

The export supply of avocados from Mexico to the U.S. 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 costs of production for approved acreage, 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:

---

[4] The simulations reported herein use the mean value of three percent. Sensitivity results over a range of values for this and other model cost and behavioral parameters are available from the authors on request.

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

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 avocados in Mexico in time period i, and x_i is the quantity of exports of avocados to the U.S. in time period i. The number of hectares in approved orchards is kept constant at its 2005 level. Estimates of compliance cost 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:

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

where *pinvest* is the 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).

2.6 Model 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 is about evenly split between the two time periods, shown as base values in the first column of Table 2.[5] California and Chile each provided about 40 percent of the avocados consumed during time

[5] Quantity of Californian Hass avocados shipped to each region is based on monthly shipment data from the Avocado Marketing Research and Information Center. 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.

period 1 and Mexico provided about 20 percent. California avocados dominate U.S. consumption during time period 2 (accounting for 75 percent). Wholesale prices of California avocados are substantially higher than prices of Chilean avocados in all demand regions in both time periods, while Chilean and Mexican avocado have similar wholesale prices in Region A during the first time period.[6] The weighted average wholesale price for California avocados across our four demand regions was $1.476 per pound during time period 1 and $1.696 per pound during time period 2. The weighted average wholesale prices for avocados from Chile were $1.176 per pound and $1.413 per pound, respectively. Producer prices for Californian avocados are nearly $0.30 per pound higher than for Chilean and Mexican avocados in period 1 and nearly $0.50 per pound higher in period 2.

The margins between producer and wholesale prices are derived by subtracting the benchmark producer prices from the benchmark wholesale prices. Because only one marketing margin is observed for Mexican avocados, that margin is used for all regions and time periods. Also, 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 and $0.026 per pound for exporters. The total cost of compliance of $0.107 is 19.8 percent of the Mexican producer price (9.9 percent of the U.S. wholesale price of Mexican avocados). 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.

3 Model Calibration

Given the prices and quantities in the benchmark period, values for the parameters in the supply and demand equations are chosen to replicate the initial equilibrium while satisfying a set of elasticities obtained from the literature.

3.1 Demand Calibration

Carman and Kraft (1998) estimated the inverse demand for California avocados using annual data from 1962 through 1995. Combining their parameter estimate with the benchmark per capita consumption of California avocados and assuming a fixed marketing margin, yields a wholesale-level demand elasticity of -1.02 for California avocados. This elasticity is then used to determine an aggregate demand elasticity for avocados from all supply regions, which is equal to the elasticity for avocados supplied by California times California's share of the total supply. The implied aggregate demand elasticity is -0.61.

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

The values of the demand elasticity for California avocados and the aggregate demand elasticity are used to determine values for the substitution elasticities in the CES utility function. Once these values have been determined, shift parameters are calculated to fit the initial benchmark data. Initial demand shift parameters for Mexican avocados are set to zero for all regions and time periods except for Region A in time period 1 to reflect the corresponding zero exports to the U.S. in the benchmark data.

3.2 Supply Calibration

Calibration of the revenue functions for California, Mexico and Chile (similar to Mexico but with zero compliance costs) depends on the aggregate supply elasticities and on the assumed elasticity of transformation. The aggregate supply elasticity for California avocados is assumed to equal 0.35 (Romano, 1998). Because less than 25 percent of the output from approved orchards was exported to the U.S. in the benchmark period, the Mexican export supply is assumed to be very elastic, a supply elasticity of 50.0. The aggregate export supply elasticity for Chile (0.64) is assumed equal to California's aggregate supply elasticity divided by 0.547, the proportion of total Chilean production exported during the benchmark period. Because of limited substitution patterns, the elasticity of transformation is set equal to 0.5 for all regions. For Mexico, the parameter δ equals 1 initially because no avocados are allowed to be exported during time period 2. In the simulations δ is set equal to 0.6 to match the proportion during time period 1 of Mexico's total worldwide exports.

3.3 Modeling Consumer Preferences with Removal of Import Restrictions

To simulate the removal of seasonal and geographic import restrictions for Mexican avocados under the 2004 rule requires that shift parameters of the CES utility function for Region A in time period 2 and for Regions B, C and D in both periods be adjusted from initial zero values used to match the absence of consumption from Mexico in the benchmark period. Following the analysis of trade policy effects on differentiated products by Venables (1987), we assume that the demand shift parameter values for avocados from Mexico that are initially zero 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 time period 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 time period 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 time period). The initial shift parameters for avocados from Chile during time period 2 are smaller in value than for time period 1 (e.g., in Region A the initial value in time period 2 is 0.1756). A larger preference bias for California avocados is justified in the second time period due to seasonal production patterns. More fresh avocados are available from California than from Chile and Mexico during the summer months.

4 Simulation Results

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 relaxed and fruit fly monitoring of orchards and quarantine requirements during harvests and packing in Mexico are also eliminated. 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.

The three simulation scenarios imply different compliance costs for Mexican growers and exporters. Compliance costs per pound will depend on the equilibrium export quantities in the first two scenarios. Eliminating fruit fly monitoring will also reduce the costs of field inspections in scenario 2. Based on cost estimates from field interviews, this would reduce the field survey costs from $130.27 per hectare in scenario 1 to $85.58 per hectare. Thus, while the cost of pest surveys increases with the requirement of conducting two surveys per year, the magnitude of the increase would be much smaller if the costs of monitoring fruit flies were eliminated. For Mexican exporters, eliminating plant quarantine requirements for fruit flies implies that the $0.005 per pound cost to upgrading their facilities would no longer be necessary. Mexican growers and exporters do not incur any compliance costs specific to exporting to the United States in the third scenario.

4.1 Pest Outbreak Frequencies and U.S. Control Costs

The frequencies of expected pest outbreaks for fruit flies and avocado stem weevil (the most damaging avocado-specific pest) and the expected costs per pound of production for pest control (*CP*) borne by California avocado orchards are shown in Appendix 1 for the three scenarios. For fruit flies, the frequency of an infestation is very low (no more than 4.0E-6 per year) under the average risk probabilities in scenario 1. The frequency increases by an order of magnitude (to at most 3.6E-5) under the high risk probabilities in scenario 1. Eliminating the compliance measures specific to fruit flies in Mexico raises the frequency of outbreaks in the United States 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 infestation reaches 0.11 in Region C during time period 1 in scenario 3. 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 total cost of fruit fly controls for expected outbreaks in Regions B and C due to importing avocados from Mexico remain low (less than a total of $124,000 for the worst case of high pest risk probabilities in scenario 3), as shown in Tables 2 and 3.

The expected frequencies are also quite low for infestations of avocado pests due to imports from Mexico in scenario 1. The frequency of an outbreak is highest for stem weevils by two orders of magnitude. The stem weevil outbreak frequencies also increase by an order of magnitude under the high pest risk probabilities (from 4.9E-3 to 4.1E-2). The avocado-specific-pest frequencies are not affected directly by removing the fruit fly compliance measures in scenario 2.[7] But in scenario 3, the avocado pest outbreak frequencies rise by two orders of magnitude. For stem weevils, expected frequency of an outbreak reaches approximately 0.75 per time period under the average pest risk probabilities and 6.5 per time period under the high pest risk probabilities. The expected frequencies of other avocado pest outbreaks remain two orders of magnitude smaller.

The expected costs of control measures borne by California orchards become substantial, particularly for the relatively frequent outbreaks of stem weevil, when the system approach compliance measures are all removed in scenario 3. These costs are estimated to be $0.01 per pound of California production in scenario 3 at the average risk probabilities. At the high risk probabilities, the seed-weevil related costs and losses reach $0.086 per pound. Thus, terminating all systems approach compliance measures 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. In addition, California growers suffer loss of output due to pest damaged fruit.

4.2 Market Equilibrium and Welfare Under Alternative Scenarios at Average Risk Probabilities

Scenario 1: Because Mexican avocados are relatively less expensive than Californian and Chilean avocados, there is a sharp net decline in demand for avocados from California and Chile. This is reflected

[7] 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 compared to scenario 1.

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 than period 1) and annual equilibrium quantity demanded and supplied falls by 11.3 percent for California avocados and by 17.1 percent for avocados from Chile.[8]

With the increased seasonal and geographic access allowed under scenario 1, annual exports from Mexico increase by 250 percent, from 58.247 million pounds to 206.956 million pounds.[9] Although compliance requirements increase with year-round shipping, this large increase in exports lowers the per-pound compliance costs in Mexico to $0.037 for growers and $0.019 for exporters, for a total of $0.056 per pound. These per-pound compliance costs are only 45.7 percent of the benchmark level for growers and 73.1 percent of the benchmark level for exporters. Although the avocado market prices in Mexico decline in both time periods, the net price received by Mexican avocado growers (producer price less their compliance costs) rises in each time period: from $0.459 per pound in the benchmark to $0.471 per pound in time period 1 and $0.500 in time period 2. The smaller increase in net price in the time period 1 is due to three factors: more avocados being exported in time period 1 (122.697 million pounds) compared to time period 2 (84.259 million pounds) due to seasonal production patterns; lower per-capita consumption in the US during time period 1; and a low elasticity of transformation. Mexican annual producer gross revenue increases from $31.453 million to $107.553 million. Total compliance costs of producers and exporters rise from $6.267 million to $11.644 million, but decline from 19.92 percent to 10.83 percent of producer revenue or weighted average producer price (over 5 percent of the wholesale price of Mexican avocados).

Expected producer surplus for California avocado growers declines by $107.651 million in scenario 1 compared to the benchmark. This decrease reflects the impact of expanded trade and the effects from small expected pest 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 $20,000. Pest control costs for fruit flies for other U.S. crops are negligible. Producer surplus also declines by $25.069 million for Chilean avocado producers, but increases by $3.108 million for Mexican avocado growers. The smaller increase in Mexican producer surplus is due to assumed relatively elastic export supply, which implies that more of the benefits of the policy change are passed onto U.S. consumers. Total U.S. avocado consumption increases from 581.071 million pounds to 660.520 million pounds. The estimated total gain

[8] The result we report for scenario 1 are similar to those reported by USDA/APHIS (2004a) in the economic analysis for the 2004 final rule.

[9] The equilibrium quantity of avocados from Mexico consumed in Region A in period 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 3 or 4 but are available from the authors.

in equivalent variation is $178.258 million for U.S. consumers across all regions and time periods. Net welfare increases by $70.607 million for the United States and by $48.646 million globally when losses and gains in Chile and Mexico are taken into account.

Scenario 2: When the compliance measures specifically for fruit flies are eliminated in scenario 2, the per-pound costs of compliance fall further for Mexican growers and exporters (to $0.031 per pound and $0.014 per pound, respectively). This additional decrease of $0.011 per pound arises primarily from lower direct compliance costs, as quantity of exports only increases by a small additional amount (by 2.722 million pounds or 1.01 percent) compared to scenario 1. Wholesale prices for Mexican avocados fall by about $0.01 in response mainly to the lower compliance costs. Producer surplus increases by $90,000. There is a small effects on quantities supplied and producer and wholesale prices of avocados from California and Chile and U.S. pestcontrol costs remain under $21,000. Producer surplus declines by $832,000 in California and by $272,000 in Chile compared to scenario 1. U.S. consumers benefit from an additional $3.493 million in equivalent variation and net U.S. and global welfare gains are $73.267 (an increase of $2.660 million compared to scenario 1) and $51.124 (an increase of $2.478 million). Thus, 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. But most of the increased trade and net welfare gains compared to the benchmark come from the removal of seasonal and geographic restrictions in scenario 1.

Scenario 3: 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 jump to $3.104 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 an additional 3.510 million pounds. Californian producer producer surplus falls by an additional $5.196 million compared to the first scenario. Chile also experiences a loss of exports and producer surplus. Mexican avocado exports increase by 14.732 million pounds compared to scenario 1 and producer surplus increases by $499,000. Again, U.S. consumers experience net gains: avocado consumption increases to 670.121 million pounds (9.601 million pounds more than scenario 1) and equivalent variation compared to the benchmark increases to $193.219 million, which is $14.961 million more than scenario 1. Net U.S. welfare increases by $80.357 million compared to the benchmark, versus an increase of $70.607 million in scenario 1, and global welfare increases in scenario 3 by $57.695 million compared to the benchmark. Thus, there is a substantial additional domestic and global welfare gain associated with eliminating all of the system approach compliance measures at the average pest risks estimated by APHIS. The additional U.S. consumer gain in this scenario is associated with a significant pest-related loss to California avocado growers because the expected frequency of pest infestations due to imports from Mexico rises and related control costs and production losses are incurred.

4.3 Adverse Effects of High Risk Probabilities

Under the assumption of the high risk probabilities estimated by APHIS the related costs have a net negative effect on California producers, U.S. consumers, and total U.S. and global welfare. In short, higher pest risk is detrimental economically. When trade is opened up with higher pest-related risks, gains to foreign producers are more than offset by adverse effects on domestic producers and consumers. These effects are quite small in scenarios 1 and 2.

Risk-related impacts become substantial in the third scenario 3. Market prices received by California producers increase to $0.624 in period 1 and $0.799 in period 2 compared to $0.577 and $0.743, respectively, under average risk probabilities. However, the net price received by California producers falls to $0.537 per pound from $0.567 per pound in period 1 and to $0.712 per pound from $0.733 in period 2, as the expected per-pound control costs for California producers rise to $0.087. Supply of California avocados declines in response to the falling net producer prices and also because of the damage to fruit from the avocado pests. The equilibrium quantity supplied annually by California growers falls to 290.008 million pounds compared to 303.433 million pounds supplied in scenario 3 under average risk probabilities. Producer surplus for California growers falls by an additional $7.128 million for scenario 3 with high risk probabilities compared to scenario 3 with average risk probabilities.

The decline in California production due to higher pest control costs and fruit damage has a deleterious effect on U.S. consumers.[10] Wholesale prices for California avocados are about $0.05 per pound higher in scenario 3 with high risk probabilities compared to scenario 3 with average risk probabilities**.** Because of the higher wholesale prices for Californian avocados, the quantity of California avocados consumed decreases by 13.425 million pounds and total avocado consumption falls by 6.648 million pounds compared to scenario 3 with average pest risks. The higher wholesale prices also imply smaller gains in equivalent variation: $17.316 million lower in scenario 3 with high risk probabilities compared to the same scenario with average risk probabilities. The net U.S. welfare gain is only $55.804 million in scenario 3 under high pest risk probabilities versus $80.357 in scenario 3 under low pest risk probabilities. The gains in equivalent variation and net U.S. welfare in scenario 3 under high pest risk probabilities are less than in scenarios 1 or 2 under either average or high risk probabilities.

The foreign avocado producers, however, are net beneficiaries in scenario 3 under high pest risk probabilities compared to low risk probabilities. The increase in producer surplus for Mexican growers is

[10] Romano first called attention to this possibility in the case of limited trade but with homogeneous products and perfectly elastic Mexican supply he did not find adverse effects on consumers with full market access.

$181,000 larger while the decrease in producer surplus for Chilean growers is $1.312 million smaller. However, these gains are not enough to offset the reduced U.S. welfare gains. The increase in global welfare in scenario 3 under high pest risk probabilities is $23.06 million lower than under average pest risk probabilities. The global welfare gain is also less for scenario 3 than for scenario 1 or 2 under the high pest risks.

5 Conclusion

A long and contentious dispute between Mexico and the United States over U.S. 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 paper has develops a model to evaluate the effects of fresh Hass avocado imports from approved orchards in Mexico under alternative systems approach pest risk mitigation measures. We find that substantially 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. Pest risks are low with the systems approach compliance measures still in place. The estimated annual net U.S. welfare gain from eliminating all geographic and seasonal restrictions is approximately $70 million.

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 greater pest risks. Compliance costs of Mexican growers and exporters fall by another 20 percent. The pest risk to U.S. producers increases by two orders of magnitude but remains low in absolute level and there is an expected additional net welfare gain of $3 million for the United States under the range APHIS-estimated risk probabilities.

The outcome is less certain if all pest risk mitigation measures against fruit flies and the targeted avocado pests are eliminated. In a best case, based on APHIS's estimated average pest infestation risk probabilities under no control measures, there is an additional gain in net U.S. welfare of $10 million compared with only eliminating 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, under the high APHIS-estimated pest risks, infestations due to imported avocados become frequent enough that California producers lose an additional $12 million in producer surplus compared to the case of year-around access to all states with the systems approach compliance measures in place. Pest-related productivity losses in California reduce the domestic supply of avocados, leading to higher consumer prices, and consumer welfare gains are reduced by more than $2 million in this worst case compared to retaining the systems approach measures. Overall, the net gain in U.S. welfare is $15 million less than the net welfare gain from only eliminating the geographic and seasonal restrictions.

Our analysis of these alternative pest-risk management import policies suggests three broad conclusions. First, the gains from the decision made by USDA to allow imports of Mexican avocados without geographic or seasonal restrictions under a systems approach hold up when pest risks and related costs are incorporated into the analysis. Second, there are modest additional gains achievable from further modification of the systems approach to reduce compliance costs associated with fruit fly control measures. Third, entirely abandoning the systems approach would be a questionable decision on pest-risk and economic criteria. By this we mean that there may be a net U.S. and global welfare gain, but it comes as a trade-off with higher pest-related control costs and losses borne by California producers. Moreover, knowledge of pest risk probabilities is not sufficient to rule out a smaller U.S. and global welfare gain in this case than occurs when some or all of the system approach compliance measures are retained.

6 References

Arndt, C. and T.W. Hertel, "Revisiting 'The fallacy of free trade'," *Review of International Economics*, 5(2) (May 1997): 221-229.

Carman, H.F. and R,K. Craft. "An Economic Evaluation of California Avocado Industry Marketing Programs, 1961-1995." Giannini Foundation Research Report Number 345, California Agricultural Experiment Station, July 1998.

Glauber, J.W. and C.A. Narrod. *A Rational Risk Policy for Regulating Plant Diseases and Pests*. Regulatory Analysis 01-05, AEI-Brookings Joint Center for Regulatory Studies, Washington, D.C., June 2001.

Orden, David and Everett Peterson. "Science, Opportunity, Traceability, Persistence and Political Will: Necessary Elements of Opening the U.S. Market to Avocados from Mexico," in *New Frontiers in Environmental and Social Labeling* (Arnab K. Basu, Nancy Chau and Ulrike Grote, editors). Springer, forthcoming 2006.

Orden, D. and E.B. Peterson. "Assessment of Costs of the 'System Approach' to Export of Mexican Avocados to the United States." Working Paper, Virginia Tech, May, 2005.

Paarlberg, P.L. and J.G. Lee. "Import Restrictions in the Presence of a Health Risk: An Illustration Using FMD." *American Journal of Agricultural Economics* 80 (February 1998): 175-183.

Rendleman, C.M. and F.J. Spinelli. "The Costs and Benefits of Animal Disease Prevention: The Case of African Swine Fever in the US." *Environmental Impact and Assessment Review* 19 (1999): 405-426.

Roberts, Donna and David Orden. "Determinants of Technical Barriers to Trade: The Case of US Phytosanitary Restrictions on Mexican Avocados, 1972-1995," in *Understanding Technical Barriers to Agricultural Trade* (David Orden and Donna Roberts, editors), St. Paul, Minnesota: University of Minnesota, Department of Applied Economics, International Agricultural Trade Research Consortium, January 1997: 117-160.

Romano, Eduardo. *Two Essays on Sanitary and Phytosanitary Barriers Affecting Agricultural Trade Between Mexico and the United States*, Ph.D. Dissertation, Virginia Polytechnic Institute and State University, April 1998.

Venables, A.J. "Trade and Trade Policy with Differentiated Products: A Chamberlinian-Ricardian Model," *The Economic Journal* 97 (September 1987): 700-717.

United States Department of Agriculture (USDA). 2004. "Mexican Avocado Import Program: Final Rule."Federal Register 7 CFR Part 319, Docket 03-022-5, pp. 69748-69774, November 30.

US Department of Agriculture, Animal and Plant Health Inspection Service (USDA/APHIS). Potential Economic Impacts of an Avocado Weevil Infestation in California. Washington, D.C., August 1993.

_______. (1995a) Importation of Avocado Fruit (*Persea americana americana*) from Mexico: Supplemental Pest Risk Assessment. Washington D.C., May 1995.

_______. (1995b) Risk Management Analysis: A Systems Approach for Mexican Avocado. Washington, D.C., May 1995.

_______. (1996) Importation of Avocado Fruit (*Persea americana americana*) from Mexico, Supplemental Pest Risk Assessment, Addendum I: Estimates for the Likelihood of Pest Outbreaks Based on the Draft Final Rule. Washington, D.C., July 1996.

_______. (2000) Economic Analysis of Options for Eradicating Mexican Fruit Fly (*Anastrepha ludens*) from the Lower Rio Grande Valley of Texas. Washington, D.C., March 2000.

_______. (2004a) Economic Analysis Final Rule: Allow Fresh Hass Avocados Grown in Approved Orchards in Approved Municipalities in Michoacan, Mexico, to be Imported Into All States Year-Round (APHIS Docket No. 03-022-3). Washington, D.C., November 5, 2004.

_______. (2004b) Importation of Avocado Fruit (*Persea americana* Mill. var. 'Hass') from Mexico: A Risk Assessment. Washington, D.C., November 19, 2004.

Table 1. Systems Approach for Avocado Imports from Mexico

Field Surveys Once per year (municipalities and orchards certification, pest free status, Michoacán only) 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 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 inspect.
Geographical Shipment Restrictions Shipments limited to Alaska only (1993), 19 states plus District of Columbia (1997), 31 states plus District of Columbia (2001), commitment to no geographic restrictions by 2007 (2004)
Seasonal Shipment Restrictions Shipping allowed only November – February (1997) (except Alaska year around), only October 15 – April 15 (2001), seasonal restrictions eliminated (2004)

Source: USDA/APHIS, 2004a.

Table 2. Market Equilibrium and Welfare Under Alternative Systems Approaches at 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
	Base Values	Simulation Outcomes		
Producer Prices	Dollars per Pound			
Time Period 1				
California	0.871	0.587	0.584	0.577
Chile	0.577	0.400	0.398	0.390
Mexico	0.540	0.508	0.502	0.470
Time Period 2				
California	1.101	0.748	0.746	0.743
Chile	0.599	0.478	0.476	0.471
Mexico	0.540	0.537	0.532	0.505
Mexican Compliance Costs				
Growers	0.081	0.037	0.031	0.000
Exporters	0.026	0.019	0.014	0.000
Wholesale Prices (Weighted Averages)				
Time Period 1 for avocados from				
California	1.476	1.189	1.186	1.179
Chile	1.176	0.989	0.987	0.980
Mexico	1.080	1.041	1.029	0.984
Time Period 2 for avocados from				
California	1.696	1.341	1.339	1.336
Chile	1.413	1.291	1.289	1.284
Mexico	1.080	1.070	1.059	1.019
Quantities Demanded and Supplied	Million Pounds			
Time Period 1 (Total Supply)	282.269	312.427	313.552	318.026
California	*115.815*	*102.452*	*102.268*	*100.814*
Chile	*108.208*	*87.278*	*87.028*	*86.112*
Mexico	*58.247*	*122.697*	*124.256*	*131.10*
Time Period 2 (Total Supply)	298.802	348.093	348.989	352.095
California	*230.196*	*204.491*	*204.338*	*202.619*
Chile	*68.605*	*59.343*	*59.229*	*58.888*
Mexico	*0.000*	*84.259*	*85.422*	*90.588*
Annual (Total Supply)	581.071	660.520	662.541	670.121
California	*346.011*	*306.943*	*306.606*	*303.433*
Chile	*176.813*	*146.621*	*146.257*	*145.000*
Mexico	*58.247*	*206.956*	*209.678*	*221.688*

Table 2 (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
	Base Values	Simulation Outcomes		
Mexican Compliance Costs	Million Dollars			
Growers	4.726	7.716	6.496	0.000
Packers	1.541	3.928	2.918	0.000
California Expected Costs of Control	0.000	0.020	0.021	3.104
Welfare Effects	Million Dollars			
Producer Surplus				
California		-107.651	-108.483	-112.847
Chile		-25.069	-25.341	-26.269
Mexico		3.108	3.198	3.607
Equivalent Variation				
Time Period 1		62.811	64.748	71.866
Region A		*9.852*	*10.632*	*13.470*
Region B		*7.584*	*7.730*	*8.350*
Region C		*30.528*	*31.205*	*33.653*
Region D		*14.847*	*15.181*	*16.393*
Time Period 2		115.448	117.003	121.354
Region A		*31.050*	*31.549*	*32.758*
Region B		*10.150*	*10.261*	*10.663*
Region C		*46.811*	*47.421*	*49.185*
Region D		*27.437*	*27.772*	*28.748*
U.S. Annual Total		178.258	181.751	193.219
Other Cost of Control – Fruit Flies		4.5E-06	9.5E-04	0.015
Net Welfare Change				
U.S.		70.607	73.267	80.357
Global		48.646	51.124	57.695

Appendix 1. Simulated Frequency of Pest Outbreaks and California Avocado Pest Control Costs Under Alternative Systems Approaches

	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						
Time Period 1						
Region B	1.0E-6	7.0E-6	1.6E-4	1.4E-3	2.5E-3	2.1E-2
Region C	4.0E-6	3.6E-5	8.7E-4	7.4E-3	1.3E-2	1.1E-1
Region D	2.0E-6	2.0E-5	4.9E-4	4.1E-3	7.5E-3	6.4E-2
Time Period 2						
Region B	1.0E-6	5.0E-6	1.2E-4	1.0E-3	1.9E-3	1.6E-2
Region C	3.0E-6	3.2E-5	7.6E-4	6.4E-3	1.2E-2	9.8E-2
Region D	2.0E-6	2.1E-5	5.0E-4	4.2E-3	7.6E-3	6.5E-2
Avocado Stem Weevil						
Time Period 1	4.9E-3	4.1E-2	4.9E-3	4.1E-2	7.5E-1	6.4
Time Period 2	4.9E-3	4.2E-2	5.0E-3	4.2E-2	7.6E-1	6.5
	Expected U.S. Control Costs (dollars per pound)					
Costs for California Avocado Orchards						
Fruit Flies	0.0E-7	1.0E-7	1.6E-6	1.4E-5	2.5E-5	2.2E-4
Seed Weevil	3.0E-7	2.4E-6	3.0E-7	2.0E-6	8.2E-5	7.6E-4
Stem Weevil	6.5E-5	5.5E-4	6.6E-5	5.6E-4	1.0E-2	8.6E-2
Seed Moth	0.0	1.0E-7	0.0	0.0E-7	2.4E-5	2.4E-4