An Economic Assessment of Removing the Partial U.S. Import Ban on Fresh Mexican Hass Avocados

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ABSTRACT

The importation of fresh Hass avocados from Mexico into the United States has been restricted, totally or partially, since 1914 on grounds of the potential risk of pest infestation. This quarantine has been a cause of dispute between the Mexican and U.S. governments. In 1997, Hass avocados from approved orchards in the State of Michoacán, Mexico, were permitted to be imported during the months of November through February into 19 northeastern states plus the District of Columbia. In 2001, the import period was extended to October 15 through April 15, and access was granted to 12 additional states. Currently there is a proposal to remove all seasonal and geographic restrictions on the importation of fresh Hass avocados from Mexico. The purpose of this research is to assess the potential economic impacts of removing the partial import ban.

A static, partial equilibrium model is constructed to analyze impacts of removing the partial import ban on Mexican avocados. Two scenarios are considered: one with population and real per-capita income held constant (short run) and one that allows growth in population and real per-capita income over five years (long run). When population and real income are held constant, removal of the partial import ban leads to an increase in avocado imports from Mexico of 102.72 million pounds (267% increase). The increased competition from Mexican avocados results in welfare losses for both Californian and Chilean avocado producers of $84.5 million and $8.5 million respectively. Conversely, consumers in the United States gain from greater availability of avocados and lower prices. The gain in equivalent variation for US consumers is $115.3 million resulting in a net welfare gain of $30.8 million for the US. For the long-run scenario, population and real per-capita income are allowed to grow at their recent historical

annual averages for five years. A five-year period is chosen to match the biological lag between planting and fruit bearing for avocados and is assumed to be the time period required for avocado producers to fully adjust to any price changes. The resulting increase in the aggregate demand for avocados significantly reduces the impact on Californian and Chilean producers of removing the partial import ban on Mexican avocados. While imports from Mexico increase by 161.4 million pounds, Californian avocado production decreases by only 14.4 million pounds and exports from Chile increase by 2.5 million pounds. The loss in producer surplus for Californian producers is $9.4 million, while the net US welfare gain is $33.2 million.

While it appears likely that the removal of the partial import ban on Mexican avocados will hurt Californian producers, growth in demand for avocados will mitigate a great deal of the potential losses. Regardless of the magnitude of the growth in demand, consumers in the United States will benefit from a greater availability of avocados at lower prices. The gain in consumer welfare more than offsets the loss in producer welfare.

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1. Introduction

Until relatively recently, entry of Hass avocados from Mexico into the United States was prohibited due to phytosanitary risks. The blanket prohibition was partially lifted in 1993, when The United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) authorized their entry into one State, Alaska. Then in November 1997, fresh Hass avocados from Mexico were allowed entry into the conterminous United States for the first time. Entry was allowed into 19 northeastern States and the District of Columbia during a four-month period, November through February.[1] In 2001, the area approved for import was expanded by an additional 12 States, and the period of import was extended to six months, October 15 to April 15.[2] In 2003, the Government of Mexico requested access for avocados from approved orchards into all 50 states throughout the year. The APHIS risk assessment for such access found an overall low likelihood of pest introduction.[3]

This paper assesses the economic impacts of allowing fresh Hass avocados from Mexico to be imported into the United States without geographic or seasonal restrictions.[4] In this Introduction, the general approach is described. Section 2 sets forth the model used for the

[1] The effective date of the final rule was March 7, 1997. The approved area included Connecticut, Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin. See Roberts and Orden (1997) for a chronology and political-economy assessment of the avocado dispute and Romano (1998) for economic assessment taking alternative pest risk estimates into account.

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

[3] "Importation of Avocado Fruit (*Persea americana* Mill. Var. 'Hass') from Mexico: A Risk Assessment." USDA APHIS, February 17, 2004 (http://www.aphis.usda.gov/ppq/avocados/2-17-04web.pdf).

[4] The analysis is the result of collaboration between APHIS and the Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University. The university's participation was supported by Cooperative Agreement 43-3AEM-3-80087, "Design of Systems Approaches to Invasive Pest Risk Management" from the Economic Research Service, USDA, under its Program of Research on the Economics of Invasive Species Management (PRESIM).

analysis, baseline data, and the model's calibration. Expected effects of the requested access on the supply and demand for Hass avocados, and a sensitivity analysis of these results, are presented in section 3. In section 4, welfare effects for U.S. Hass avocado producers and consumers are examined, and a brief conclusion is given in section 5.

The impact of allowing Hass avocados from Mexico to be imported into all States year-round is analyzed using a static, partial equilibrium model with avocados from different sources assumed to be heterogeneous goods. Initial quantities and prices used in the model are based on a two-year period, October 15, 2000 to October 15, 2002. The model has three demand regions: 31 northeastern and central States (and the District of Columbia) currently approved to receive Hass avocado imports from Mexico during the 6-month period, October 15-April 15 (Region A); 16 Pacific and southern States, excluding California and Florida, not currently approved to receive Hass avocados from Mexico (Region B); and California and Florida (Region C).[5] Separation of California and Florida into a third region is based on much higher per capita demand for Hass avocados compared to other States. During the baseline period, per capita Hass avocado consumption in California and Florida is estimated to have been 4.2 pounds per year, compared to 1 pound and 2.2 pounds per year for Regions A and B, respectively.

There are three supply regions in the model: California, Mexico, and Chile. Nearly all U.S. Hass avocado production takes place in California, while over 96 percent of all Hass avocado imports are supplied by Chile and Mexico.[6] Two time periods are specified in the

[5] States not approved to receive Hass avocados from Mexico are Alabama, Arizona, Arkansas, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, Nevada, New Mexico, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, Texas, and Washington. As mentioned, Hass avocados from Mexico have been allowed to be imported year-round into Alaska since 1993.

[6] Production of the Hass variety in Florida and Hawaii is negligible (Florida and Hawaii Agricultural Statistics Services). About 80 percent of California's avocado production is of the Hass variety (California Avocado Commission). The percentage imports from Chile and Mexico is based on trade data from the U.S. Census Bureau, July 2001-April 2003. July 2001 was the first month in which Hass avocado imports were distinguished from

model, given the current six-month restriction on Hass avocado imports from Mexico: October 15-April 15 (Period 1); and April 15-October 15 (Period 2).

Briefly, the analysis is based on a set of equations that describe, on the demand side, Hass avocado consumption in the United States, and on the supply side, foreign and domestic Hass avocado production for the U.S. market. We begin by specifying short-run and long-run constant elasticities of substitution and transformation, based on demand and supply elasticities from the literature. The elasticities of substitution and transformation are used in the demand and supply equations to replicate baseline quantities and prices, yielding parameter values for the model. The equations are then resolved for the short-run and long-run scenarios, with parameters altered to account for greater access to U.S. markets afforded Hass avocado imports from Mexico.

Two scenarios are evaluated in this paper. The first is a short-run scenario that assumes fixed demand (no increases in population or income) and an inelastic supply. The second scenario combines demand growth (increases in population and real income over five years) and an elastic supply to describe expected long-run effects of requested access. The long-run scenario is not a comparison of conditions "with" and "without" the unrestricted access after five years. Rather, it is a comparison to the baseline of the supply and demand for avocados after five years of unrestricted access, in order to show the effects of population and real income growth. Resulting changes in prices and quantities provide the basis for approximating welfare impacts for U.S. Hass avocado consumers and producers. In the following sections, "avocado" refers only to fresh Hass avocados unless otherwise indicated.

imports of other avocado varieties. Throughout the paper, "avocado" refers only to fresh Hass avocados unless otherwise indicated.

2. The Model, Data, and Model Calibration

The model's framework is summarized in table 1. The model has 34 endogenous variables and equations, and 28 exogenous variables.[7] The 34 endogenous variables are (i) the quantities of avocados consumed in each demand region provided by each supply region during each time period, (ii) the wholesale price index in each demand region in each time period, (iii) producer prices in California and Chile in each time period, (iv) quantities of avocados supplied by California and Chile in each time period, and (v) the levels of factor endowment in California and Chile. The 28 exogenous variables are (i) the populations in each demand region, (ii) per capita incomes in each demand region in each time period, (iii) marketing margins in each demand region for avocados provided by each supply region during each time period, and (iv) the producer price in Mexico (considered the same for both time periods).

Demand. The demand for avocados is derived from a weakly separable (nested Constant Elasticity of Substitution (CES)) utility function for a representative consumer. The utility function is assumed to contain a partition of all goods purchased by consumers: avocados and everything else. In addition, avocados produced in each of the three supply regions are assumed to be heterogeneous products. This assumption rests on observed wholesale price differentials in 14 cities, as described below. Thus, there are two different substitution possibilities in consumption. The parameter σ_2 represents the elasticity of substitution between avocados from the different supply regions. The parameter σ_1 represents the elasticity of substitution between avocados from all supply regions and all other goods. An overall decrease in the relative price of avocados (represented by a price index) would lead to the representative consumer increasing his

[7] This paper focuses on a narrative description of the model and scenario results. A complete set of technical appendices for the analysis is available from the authors.

Table 1. Model Framework

3 Demand Regions	• *Region A* States approved to receive Hass avocados from Mexico between October 15 and April 15 • *Region B* States not approved to receive Hass avocados from Mexico, excluding California and Florida • *Region C* California and Florida
3 Supply Regions	• California • Chile • Mexico
2 Time Periods	• *Period 1* October 15 to April 15 • *Period 2* April 15 to October 15
2 Scenarios	• *Short Run* No increase in population or income, inelastic supply • *Long Run* Five-year increase in population and income, elastic supply

or her consumption of avocados from all regions.[8] Thus the value of the parameter σ_1 will determine the magnitude of the own-price aggregate demand elasticity for avocados in the model. Two sets of σ_1 and σ_2 parameters are specified, one set for the short-run scenario and one set for the long-run scenario.

Supply. Because ripe avocados may be left on the tree for many months before harvesting, it is possible for producers to shift avocado sales between time periods as relative prices change. A Constant Elasticity of Transformation (CET) production possibility frontier is used to capture this possibility. Like the CES utility function, the main advantage of using a CET function is that it is parsimonious in the parameters. Only a single, constant elasticity of transformation must be chosen in order to apply this functional form.

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

The "supply" of avocados refers to the quantity of avocados sold in the United States. Because 95 percent of avocados produced in California are consumed in the United States, the supply of avocados from California is used to represent the total production of avocados in that region. The supply of avocados by Chile and Mexico is an export supply since the U.S. market is only one of several destinations. In the model, avocados supplied by Chile should therefore be more price responsive than avocados supplied by California. This distinction is important when choosing the supply elasticity (aggregated across the two time periods) for Chile, and is discussed further with respect to the model's calibration.

Currently, Mexico is exporting to the United States a fraction of the avocados that could be exported from approved orchards and municipalities in the State of Michoacán. An estimated 479 million pounds of fresh avocados could be certified for export to the United States.[9] From October 15, 2002 through April 15, 2003, imports from Mexico totaled approximately 64.2 million pounds, or 13.4 percent of what potentially could be certified for export to the United States. It is apparent that Mexican producers could readily expand their level of exports to the United States at the current price level. Compared to an average wholesale price in the United States of $1.14 per pound during the baseline period (October 15, 2000 to October 15, 2002), the average wholesale price in Mexico in 2001 was $0.46 per pound, and in 2002, $0.37 per pound.[10] Thus, we assume in the model that the export supply of avocados from Mexico is perfectly elastic, and that the price Mexico's producers receive for their exports is fixed.

[9] This estimate for the 2003/04 marketing year is based on 21,400 hectares certified for export to the United States times an average production of 10.15 metric tons per hectare for a total of 217,210 metric tons or 479 million pounds (USDA Foreign Agricultural Service, Global Agriculture Information Network, Report number MX3153 [11/14/03]).

[10] USDA Foreign Agricultural Service, Global Agriculture Information Network, Report numbers MX2170 (12/13/02) and MX3153 (11/14/03).

Baseline Data

The set of prices and quantities that represents an initial equilibrium, shown in table 2, constitutes the baseline. All prices and quantities are averages from the two-year period, October 15, 2000 to October 15, 2002. A two-year period smoothes out annual fluctuations and is chosen over a longer base period to reflect the increases in imports from Mexico and Chile in recent years. Technical aspects of estimating a distribution of quantities among the demand regions, and of the derivation of the baseline producer and wholesale prices, are described in the notes to table 2. The margins between producer prices (FOB for California, CIF for Chile and Mexico) and wholesale prices are derived by subtracting the baseline producer prices from the baseline wholesale prices in table 2. The dollar values per pound of all margins are assumed to remain constant in all model simulations.

Table 2. Baseline Data Used in the Model

	Supply Region		
Quantity Demanded	California[1]	Chile[2]	Mexico[2]
Time Period 1		Million Pounds	
Region A	18.226926	10.200527	38.449997
Region B	52.283282	30.859195	0
Region C	57.612707	33.838534	0
Time period 2			
Region A	62.629213	12.015264	0
Region B	86.854244	16.700523	0
Region C	99.022757	18.950326	0
Wholesale Prices[3]			
Time period 1		Dollars per Pound	
Region A	1.5388	1.1956	1.1396
Region B	1.5648	1.3030	N/A
Region C	1.4653	1.1840	N/A
Time period 2			
Region A	1.4661	1.2439	N/A
Region B	1.5389	1.4016	N/A
Region C	1.4415	1.1000	N/A
Producer prices			
Time period 1	0.8775	0.5342	0.6327
Time period 2	0.9131	0.4998	N/A

	Supply Region		
Quantity Demanded	California[1]	Chile[2]	Mexico[2]
	Demand Region		
	Region A	*Region B*	*Region C*
Per-capita income			
Time period 1	$16,047.58	$13,598.37	$15,898.56
Time period 2	$16,255.01	$13,824.79	$16,029.94
		Millions	
Population	146.236	85.167	50.518

Sources: Quantities: California based on data provided by the Avocado Marketing Research and Information Center (AMRIC); Chile and Mexico from the U.S. Census Bureau as reported in the World Trade Atlas. Wholesale prices: Market News Archive, USDA Agricultural Marketing Service, Wholesale Market Fruit Reports (various issues). Producer prices: California avocado prices are FOB prices reported by the California Avocado Commission; Chilean and Mexican prices are unit CIF import prices reported by USDA FAS. Per capita income: State quarterly personal income from U.S. Department of Commerce, Bureau of Economic Analysis. Population: mid-year State population estimates from U.S. Census Bureau.

[1] AMRIC monthly data are reported for terminal markets located within the six regions: Northeast, East Central, West Central, Pacific, Southwest, and Southeast. The Pacific region includes shipment terminals in Idaho and Utah. States currently approved to receive Hass avocados from Mexico correspond to those having terminal markets in AMRIC's Northeast, East Central, and West Central regions, plus Idaho and Utah. States with terminal markets in the Pacific, Southwest, and Southeast regions correspond to States prohibited from receiving Mexican Hass avocados, minus Idaho and Utah. Since the quantity of Hass avocados shipped to these two States is small, this discrepancy can be disregarded in using AMRIC's regional shipment data. April and October quantities are divided evenly between the two time periods.

[2] Avocado import data do not distinguish between whole fresh avocado imports and processed avocado imports. Quantities may therefore be somewhat inflated. Hass avocado imports began to be reported separately from other avocado imports in July 2001 (Harmonized Schedule 0804.40.0010). Reported import quantities from Chile and Mexico for October 2000 through June 2001 are multiplied by 99.6 percent and 98.8 percent, respectively, the percentages of imports identified as Hass from July 2001 through April 2003. For imports from Chile for each time period, regional quantities are assumed to be proportional to regional shipments reported for California. For example, for the period 4/15/01 to 10/15/01, about 25 percent of Hass avocados supplied by California were shipped to the Northeast, East Central, and West Central regions; about 35 percent were shipped to the Pacific, Southwest, and Southeast regions, excluding California and Florida; and about 40 percent remained in California or were shipped to Florida. The same proportional shares are assumed for imports from Chile during this period. As with the California supply, April and October quantities supplied by Chile are divided evenly between the two time periods.

For imports from Mexico, April and October quantities are fully included within Period 1, given the relatively small amounts that are otherwise exported to Alaska (the only State allowed to receive Hass avocado imports from Mexico year-round) or processed. May through September shipments (imports of fresh avocados into Alaska and imports of processed avocados) are excluded from the analysis.

[3] Wholesale avocado price data were available for Atlanta, Baltimore, Boston, Chicago, Dallas, Detroit, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco, Seattle, and St. Louis. During the period October 2000 through September 2001, the average wholesale price for California avocados was $1.505 per pound, while the average wholesale prices for avocados from Mexico and Chile were $1.14 per pound and $1.222 per pound, respectively.

Model Calibration

Given the initial values of all prices and quantities, values for parameters in the model are chosen such that the model can replicate the initial equilibrium while satisfying a set of supply and demand elasticities obtained from the literature. This subsection describes the calibration process.

Demand Elasticities. Little existing empirical evidence exists on the magnitude of demand elasticities for avocados. Carman and Kraft (1998) estimated the inverse demand for California avocados using annual data from 1962 through 1995. They obtained a price flexibility of –1.33 when per capita consumption of California avocados equals 1.012 pounds and the producer price of avocados, deflated by the consumer price index (1982-84 base) equals 51.286 cents per pound. Because per capita consumption in our baseline data is higher, 1.336 pounds, and the real producer price is lower, 50.666 cents per pound, the flexibility estimate from Carman and Kraft must be adjusted. Using the parameter estimates reported in equation (10) in Carman and Kraft, our baseline per capita consumption of California avocados and real producer price yield a short-run price flexibility of –1.75, or a demand elasticity of –0.57.

Because the demand elasticity estimate derived from Carman and Kraft is for producer prices, it also must be adjusted to the wholesale level to be consistent with this model. In making this adjustment, we assume the fixed marketing margin. In the baseline data, the average ratio of wholesale price to producer price for California avocados across all markets and time periods is 1.679. The wholesale-level demand elasticity is obtained by multiplying the producer-level demand elasticity by the ratio of the wholesale price to the producer price. This yields a wholesale-level demand elasticity of –0.96 for California avocados.

The wholesale-level demand elasticity for California avocados is used to determine an aggregate demand elasticity for avocados from all supply regions. This aggregated own-price demand elasticity equals the own-price elasticity for avocados supplied by California times California's share of the total supply. In the baseline data, the average quantity share of California avocados across all demand regions and time periods is 0.70. Thus, the implied aggregate short-run demand elasticity is equal to –0.67.

The short-run values of the own-price demand elasticity for California avocados and the aggregate own-price demand elasticity are used to determine values for σ_1 and σ_2. Once these values of σ_1 and σ_2 have been determined, the other preference parameters can be calculated for the short-run scenario by solving a system of non-linear equations.

The same process is used to specify the long-run values for σ_1 and σ_2, taking into consideration the extended time period. The estimated price flexibility for California avocados from Carman and Kraft is based on annual data. The demand elasticity estimate over five years should be more elastic than one based on annual data. Carman and Kraft also estimated a demand model based on monthly data. The estimated price flexibility (at the mean of their data) was –1.54, compared to a price flexibility of –1.33 using annual data. Thus, the annual demand elasticity is approximately 15 percent larger (in absolute terms) than the monthly demand elasticity. Assuming that the demand elasticity increases by 15 percent per year, we increase the annual Carman and Kraft estimate by 75 percent. The long-run producer-level demand elasticity is assumed to be –1.0.

As in the short-run scenario, this elasticity is adjusted to the wholesale level by the assumed fixed marketing margin. Multiplying the implied long-run producer-level demand elasticity of –1.0 times 1.679 yields a wholesale-level demand elasticity of –1.68 for California avocados. As before, the long-run aggregate demand elasticity equals the long-run elasticity for avocados supplied by California times California's share of the total supply (70 percent). The implied aggregate long-run demand elasticity is equal to –1.18.

The long-run values of the own-price demand elasticity for California avocados and the aggregate own-price demand elasticity are used to determine the appropriate long-run values of σ_1 and σ_2. The long-run preference parameters are then calculated.

Aggregate Supply Elasticities. Calibration of the revenue functions for California and Chile depends on the assumed elasticity of transformation, that is, the ease with which avocado producers can shift their sales between the two time periods as relative producer prices between the periods change. The other factor supply parameters used in the model can then be calculated. In addition, aggregate supply elasticities for California and Chile determine how easily they can expand or contract total production as the avocado price index changes. In their study, Carman and Kraft estimated that the supply elasticity for California avocados ranged from approximately 0.2 in the short-run to a maximum of 1.3 in the long-run. Romano (1998) used an aggregate supply elasticity of 0.35 for California avocados.

In this study, two alternative aggregate supply elasticities for California are considered: 0.35 and 1.3, representing short-run and long-run supply response scenarios. For Chile, because the relevant supply elasticities are for export supply, not total supply, the short-run and long-run aggregate supply elasticities must be adjusted based on the percentage of Chilean production that is exported. During the years 2000 to 2002, Chilean avocado producers exported 54.7 percent of their total production. Thus, the short-run and long-run aggregate supply elasticities for Chile are equal to California's aggregate supply elasticities divided by 0.547.

Removal of Import Restrictions

To simulate the removal of import restrictions on Mexican avocados across time periods and demand regions requires that some of the initial preference parameters be adjusted. These are parameters that have initial values of zero because of the baseline phytosanitary restrictions: for avocados from Mexico in Regions B and C (Pacific and southern States) at all times and in Region A (northeastern and central States) during Period 2. Without adjusting these parameters, the model cannot show the effect on U.S. avocado demand of removing the import restrictions. This raises the issue of how to adjust the parameter values.

Following the work of Venables (1987) on trade policy with differentiated products, we assume that with removal of import restrictions, preference parameter values for avocados from Mexico that are initially zero can be set equal to the preference parameter values for Chilean avocados, by demand region and time period. The preference parameter for California avocados is decreased by the same amount to ensure that they continue to sum to one for each demand region in each time period. This same procedure is followed in both scenarios.

3. Effects on Supply and Demand

A Classification of Effects

Removal of restrictions on Mexican avocado imports will increase their supply and affect the supply and demand for avocados from California and Chile. The impacts on demand are of four types: a varietal effect, a substitution effect, an expansion effect, and a population effect. The relative magnitude of these effects is addressed below in the discussion of short-run and long-run impacts.

- The varietal effect refers to changes in the initial preference parameters. A reduction in the preference parameter for avocados from any of the three supply regions results in a decrease in their demand. The magnitude of this effect is measured by comparing per capita demand for avocados in each demand region from each supply region after the restrictions have been removed (holding prices and income constant), to their initial per capita demand.

- The substitution effect determines how changes in the relative wholesale prices of avocados affect the demand for avocados from each supply region. Because the wholesale price of Mexican avocados is assumed to remain constant, relative decreases in the wholesale price of avocados from California and Chile will cause their increased consumption. The magnitude of this effect is determined by comparing per capita consumption for avocados in each demand region from each supply region at initial prices, using the changed preference parameters, to per capita consumption at the new prices, holding avocado expenditures constant.

- The expansion effect measures the increase in the demand for avocados from all three supply regions. It is composed of a price effect and an income effect. A decrease in the avocado price index (*PI*) leads to an increase in the demand for all avocados because avocados are relatively less expensive than the composite "all other goods," whose price is held constant. In addition, in the long-run scenario the increase in real per capita income increases the demand for all avocados. Because the long-run aggregate demand for avocados is assumed to be elastic, both of these effects will increase the total level of expenditures on avocados. The expansion effect is measured by comparing per capita consumption at initial prices and avocado expenditures, using the changed preference parameters, to per capita consumption at initial prices and the changed level of avocado expenditures.

- Finally, because the demand equations are specified on a per capita basis, an increase in the population will lead to a proportional increase in the aggregate demand for all avocados.

Short-run Scenario (Fixed Demand)

Mexican avocados imported for the first time into Region A during Period 2 and into Regions B and C throughout the year will affect the supply of avocados by California and Chile to all of the demand regions. The short-run impacts on quantities and prices are shown in the upper half of table 3. Overall, avocado consumption increases by 10.4 percent. Quantities supplied by California and Chile decline by 9.5 percent and 8.9 percent, respectively, while imports from Mexico increase to nearly 3.7 times their initial level, from 38.5 million pounds to over 141 million pounds.

Table 3. Summary of Short-run and Long-run Changes in Quantities and Prices[a]

Short-Run Scenario[b]	Initial Prices and Quantities[c]	Increased Access	Change	Percentage Change
	Million Pounds			
Quantity				
Total	537.643	593.785	+56.142	+10.4%
Supplied by:				
California	376.629	340.895	-35.734	-9.5%
Chile	122.564	111.715	-10.849	-8.9%
Mexico	38.450	141.174	+102.724	+267.2%
	Dollars per Pound			
Wholesale Price of Avocados Supplied by:				
California	$1.49	$1.26	-$0.23	-15.4%
Chile	$1.24	$1.16	$0.08	-6.5%
Producer Price for:				
California	$0.90	$0.67	$0.23	-25.6%
Chile	$0.52	$0.45	$0.07	-13.5%
Long-Run Scenario[e]				
	Million Pounds			
Quantity				
Total	537.643	687.249	+149.606	+27.8%
Supplied by:				
California	376.629	362.269	-14.360	-3.8%
Chile	122.564	125.095	+2.531	+2.1%
Mexico	38.450	199.885	+161.435	+419.9%
	Dollars per Pound			
Wholesale Price of Avocados Supplied by:				
California	$1.49	$1.47	-$0.02	-1.3%
Chile	$1.24	$1.24	$0.00	0.0%
Producer Price for:				
California	$0.90	$0.88	-$0.02	-2.2%
Chile	$0.52	$0.53	+$0.01	+1.9%

[a]Based on quantities and prices in table 2. Prices weighted by regional and time period quantities.
[b]Fixed demand (no income or population growth). Short-run aggregate supply elasticity for California of 0.35.
[c]Baseline.
[d]Effects of increased access on quantities and prices (simulation results).
[e]Demand growth after five years. Annual rate of real income growth of 2.2 percent; annual rates of population growth of 0.7 percent in Region A, 1.7 percent in Region B, and 1.5 percent in Region C. Long-run aggregate supply elasticity for California of 1.3.

Given the inelastic supply in the short run, the decline in price is of greater significance for California producers than is the decline in quantity. California's prices fall by 15.4 percent at the wholesale level and 25.6 percent at the producer level. Price impacts for avocados supplied by Chile are smaller, since their initial price is much closer to that of avocados from Mexico.

Effects by demand region, supply region, and time period are shown in table 4. Two-thirds of avocado imports from Mexico enter during Period 1 (October 15-April 15).[11] In Regions B and C during Period 1, avocados from Mexico displace 30 percent and 23 percent of the avocados that had been supplied by California.

Because overall demand for avocados from California and Chile decreases in both time periods, wholesale and producer prices for avocados from California and Chile also decrease in both time periods. Imports from Mexico during Period 1 comprise a larger share of total avocado consumption, and therefore exert greater downward pressure than during Period 2 on prices of avocados supplied by California and, to a lesser extent, on Chilean avocado prices.

To better understand the changes in demand, they can be decomposed into the effects identified at the beginning of this section.[12] There are two general results for the short-run scenario. First, because the price of Californian avocados decreases relative to Chilean and Mexican avocados, there is a positive substitution effect for Californian avocados and a negative substitution effect for Mexican avocados. Second, because the aggregate demand for avocados in the short-run is price inelastic, the expansion effect is negative for all avocados across all regions and time periods.

[11] Historically, approximately 60 percent of Mexico's avocado exports occur during the October 15-April 15 time period (Mexico's Secretary of Economy, as reported in the World Trade Atlas).

[12] Since population is held constant in the short-run scenario, the population effect is zero.

Table 4. Simulation Results

	Initial Prices and Quantities[c]	Short-Run[a] Increased Access[d]	Short-Run[a] Mean[e]	Short-Run[a] Std Dev[f]	Long-Run[b] Increased Access[g]	Long-Run[b] Mean[h]	Long-Run[b] Std Dev[i]
Quantity Demand			Million Pounds				
Time Period 1[j]							
Region A							
California	18.227	25.572	25.897	1.140	25.023	25.128	0.934
Chile	10.201	10.358	10.459	0.258	11.513	11.533	0.515
Mexico	38.450	34.180	34.022	0.639	42.025	42.064	3.105
Region B							
California	52.283	37.012	37.438	1.558	41.816	42.020	1.691
Chile	30.859	27.036	27.245	0.473	29.733	29.772	1.522
Mexico	0.000	30.876	30.729	0.729	45.524	45.724	3.723
Region C							
California	57.613	44.525	45.063	2.000	51.032	51.303	2.122
Chile	33.839	30.359	30.608	0.554	34.049	34.103	1.718
Mexico	0.000	28.542	28.372	0.728	37.538	37.613	3.039
Time Period 2[k]							
Region A							
California	62.629	58.909	59.084	1.933	59.580	59.578	2.025
Chile	12.015	11.078	11.124	0.125	12.207	12.179	0.645
Mexico	0.000	11.933	11.927	0.442	17.767	17.884	1.646
Region B							
California	86.854	78.402	78.626	2.536	80.548	80.494	2.810
Chile	16.701	15.182	15.236	0.138	17.248	17.206	0.950
Mexico	0.000	20.733	20.736	0.863	37.341	37.704	3.761
Region C							
California	99.023	96.474	96.753	3.086	104.270	104.303	3.837
Chile	18.950	17.702	17.790	0.275	20.345	20.295	1.056
Mexico	0.000	14.910	14.896	0.594	19.690	19.770	1.869
California Production	376.629	340.895	342.860	12.199	362.269	362.827	12.099
Imports from Chile	122.564	111.715	112.480	1.813	125.095	125.089	6.257
Imports from Mexico	38.450	141.174	140.682	3.996	199.885	200.759	16.564
Producer Price			Dollars per Pound				
Time Period 1							
California	$0.878	$0.549	$0.538	$0.045	$0.778	$0.776	$0.025
Chile	$0.534	$0.453	$0.445	$0.023	$0.523	$0.522	$0.012
Time Period 2							
California	$0.913	$0.723	$0.721	$0.049	$0.925	$0.926	$0.027
Chile	$0.500	$0.441	$0.438	$0.030	$0.529	$0.530	$0.016

Table 4. Continued

	Initial Prices and Quantities[c]	Short-Run[a]			Long-Run[b]		
		Increased Access[d]	Mean[e]	Std Dev[f]	Increased Access[g]	Mean[h]	Std Dev[i]
Wholesale Price			Dollars per Pound				
Time Period 1							
Region A							
California	$1.539	$1.210	$1.199	$0.045	$1.439	$1.437	$0.025
Chile	$1.196	$1.115	$1.107	$0.023	$1.184	$1.184	$0.012
Mexico	$1.140						
Region B							
California	$1.565	$1.236	$1.225	$0.045	$1.465	$1.463	$0.025
Chile	$1.303	$1.222	$1.214	$0.023	$1.292	$1.291	$0.012
Mexico	$1.140						
Region C							
California	$1.465	$1.137	$1.126	$0.045	$1.365	$1.363	$0.025
Chile	$1.184	$1.103	$1.095	$0.023	$1.173	$1.172	$0.012
Mexico	$1.140						
Time Period 2							
Region A							
California	$1.466	$1.276	$1.274	$0.049	$1.478	$1.479	$0.027
Chile	$1.244	$1.185	$1.182	$0.030	$1.273	$1.274	$0.016
Mexico	$1.140						
Region B							
California	$1.539	$1.349	$1.347	$0.049	$1.551	$1.551	$0.027
Chile	$1.402	$1.343	$1.340	$0.030	$1.430	$1.432	$0.016
Mexico	$1.140						
Region C							
California	$1.441	$1.252	$1.249	$0.049	$1.453	$1.454	$0.027
Chile	$1.100	$1.041	$1.038	$0.030	$1.129	$1.130	$0.016
Mexico	$1.140						

[a]Fixed demand (no income or population growth). Short-run aggregate supply elasticity for California of 0.35.
[b]Demand growth after five years. Annual rate of real income growth of 2.2 percent; annual rates of population growth of 0.7 percent in Region A, 1.7 percent in Region B, and 1.5 percent in Region C. Long-run aggregate supply elasticity for California of 1.3.
[c]Baseline.
[d]Effects of increased access on quantities and prices (simulation results) in the short-run scenario.
[e]Mean values of the short-run sensitivity analysis distributions.
[f]Standard deviations of the short-run sensitivity analysis distributions.
[g]Effects of increased access on quantities and prices (simulation results) in the long-run scenario.
[h]iMean values of the long-run sensitivity analysis distributions.
[i]Standard deviations of the long-run sensitivity analysis distributions.

For Region A in Period 1 in the short-run scenario, the consumption of avocados from California increases while the consumption of avocados from Mexico decreases (the consumption of avocados from Chile remains largely unchanged). This shift is mainly due to a large decline in the wholesale price of avocados from California, relative to the wholesale price of Mexican avocados. In this region during Period 2, the varietal effect for California and Mexico outweigh the substitution effects, leading to a decrease in the consumption of California avocados when Mexican avocados are no longer restricted.

For Regions B and C, the largest varietal effect occur during Period 1: In Region B, an increase of 35.3 million pounds for avocados from Mexico, and decreases of 25.3 million pounds and 3.5 million pounds for avocados from California and Chile; in Region C, an increase of 33.3 million pounds for avocados from Mexico, and decreases of 25.6 million pounds and 2.9 million pounds for avocados from California and Chile.[13] These are the largest varietal effect because more avocados are imported in Period 1 than in Period 2 in the initial equilibrium.

Results of a sensitivity analysis conducted to consider alternative values for several key parameters and exogenous variables are also reported in table 4, in recognition of the uncertainty surrounding these values. The sensitivity analysis is conducted with respect to the elasticities of substitution in demand (σ_1 and σ_2), the elasticities of transformation and aggregate supply, and (for the long-run scenario) the rates of population growth in the demand regions and the rate of growth in per capita real income. Because no information is available about the distributions of these parameters and exogenous variables, uniform distributions are assumed within the specified ranges considered.

The results of the sensitivity analysis are given in the mean and standard deviation columns in table 4. Relative to the baseline and mean values, the standard deviations are small for all of the reported endogenous variables. These results indicate that the simulation results

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[13] Because the CES utility function is "variety loving" (see Venables 1987), the positive varietal effect for Mexican avocados offsets the negative varietal effect for avocados from California and Chile.

vary little for the given range of parameters and exogenous variables used in modeling impacts of removing the restrictions on avocado imports from Mexico.

Long-run Scenario (Demand Growth)

To account for effects of demand growth, population and real per capita income are increased in the long-run scenario, based on observed growth rates for the three demand regions. During the late 1990s and up to 2002, real per capita personal income grew at an annual rate of approximately 2.2 percent in each region. Population in Region A grew at an annual rate of 0.7 percent, compared to 1.7 percent in Region B, and 1.5 percent in Region C. These observed growth rates and a five-year adjustment period (the lag between planting and production) are used to increase the exogenous levels of population and per capita real income, and the model is resolved using the long-run supply elasticities.

Long-run impacts are shown in the lower half of table 3. When the increase in overall demand for avocados due to income and population growth over five years is included in the model, avocado imports from Mexico increase by over 160 million pounds to nearly 200 million pounds. This increase is 57 percent greater than the increase in avocado imports from Mexico in the short-run scenario. For Chilean avocados, the increase in demand because of income and population growth more than offsets the decrease in demand due to the increased competition from Mexican avocados. Imports of Chilean avocados increase by 2.5 million pounds, or 2.1 percent. After five years of demand growth, the quantity of avocados supplied by California declines by 14.4 million pounds (3.8 percent) from the initial quantity, compared to a decline of 35.7 million pounds (9.5 percent) in the short-run scenario.

Producer prices for California and Chile fall during Period 1, as in the short-run scenario, but increase in Period 2 (table 4). For California avocados, the increase in producer price is due to a combination of a decrease in supply (shift in the supply function) and an increase (shift) in demand. Because of the producer price decrease during Period 1 is larger than the producer price increase during Period 2, the California producer price index (*PP*) decreases, leading to a reduction in the overall production and aggregate supply of California avocados.[14]

With respect to the long-run consumption of California avocados (other than in Region A in Period 1), the negative varietal effect outweigh the positive expansion and population effects in all instances except in Region C in Period 2, when the opposite is true (table 4). The substitution effect is sometimes positive and sometimes negative. The interaction between changes in the quantity supplied and changes in producer prices depends on the size of the elasticity of transformation (σ_T), that is, the ability of California producers to shift sales between the two time periods. In results not shown, an increase in the absolute value of σ_T for California producers from its baseline value of -0.5 to -1.0 allows enough production to be shifted from Period 1 to eliminate the producer price increase during Period 2. However, increasing the elasticity of transformation does not affect the reduction in the aggregate supply of California avocados.

For avocados from Chile in the long-run scenario, the positive expansion and population effects are large enough to more than offset the negative varietal and substitution effects, leading to an increase in demand for Chilean avocados in all regions and time periods except in Region B in Period 1. This increase in demand leads to an increase in the wholesale price and thus the producer price of Chilean avocados in Period 2, prompting an increase in the aggregate export supply of avocados from Chile. The Chilean producer price falls slightly in Period 1 because the increase (or shift) in the export supply is greater than the increase in demand.

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[14] The reduction in aggregate supply causes the production possibilities frontier to shift inward, implying that supply functions in each time period also shift inward.

Given that the growth in demand for avocados can mitigate some of the negative impacts on California producers of removing restrictions on Mexican avocado imports, an interesting question arises: How much would the demand for avocados have to grow to eliminate the negative impacts entirely? In a simulation (the results of which are not reported here) where the growth of real per capita income is doubled to an annual rate of 4.4 percent (the highest value used in the sensitivity analysis) and the same annual population growth rates as above are assumed, the aggregate supply of California avocados increases by 5.3 million pounds, or 1.4 percent, from the initial equilibrium. In other words, this overall growth in the demand for avocados would be sufficient to absorb all imports from Mexico and Chile, plus a small increase in Californian production. While a doubling of the rate of real income growth is unlikely, a larger income growth rate can serve as a proxy for higher income elasticities of demand. Given that the unitary income elasticities in the CES demand system are about half of Carman and Kraft's implied income elasticity for California avocados, the effects of a higher income growth rate more closely reflect Carman and Kraft's estimated income effects.

4. Welfare Effects

Removing restrictions on Mexican avocado imports will affect both consumers and producers. For U.S. consumers, equivalent variation (EV) is used to quantify the change in their welfare. The results for each demand region and time period are presented in table 5. Total EV across all regions and time periods ranges from $115.3 million in the short-run scenario when population and income are held constant to $42.6 million in the long-run scenario. The difference in EV for the short-run and long-run scenarios is due to the relative magnitude of the changes in producer (and therefore wholesale) avocado prices. When the avocado supply response is inelastic, there is a much larger decrease in avocado prices, which would allow consumers to achieve a higher level of utility following the removal of restrictions.

In terms of the distribution of EV across regions and time periods, not surprisingly, consumers in Region A in Period 1 gain the least, since this is the region already approved to receive avocados from Mexico. Consumer gains in Regions B and C are similar for both time periods in the short run. In the long-run scenario, regional and time period distinctions are more apparent. When five-year increases in population and real income are included, over 70 percent of the gain occurs in Period 1, when higher imports of Mexican avocados lead to relatively lower prices for avocados from California and Chile. In Period 2, over 60 percent of welfare gains go to consumers in Region B.

The welfare impacts for avocado producers in California and Chile are determined by computing the change in producer surplus based on their avocado factor endowment supply curves.[15] Given the decline in producer prices, California avocado producers experience welfare losses in both scenarios, but losses are significantly larger in the short run: $84.5 million compared to $9.4 million in the long run (table 5). Chile's suppliers lose producer surplus in the short-run scenario equivalent to $8.5 million, but enjoy a slight gain of $0.6 million in the long run.

The net change in U.S. welfare is computed by summing the equivalent variation for consumers across regions and time periods and subtracting the loss in producer surplus to California producers. As shown in table 5, the net welfare gains are $30.8 million in the short-run scenario and $33.2 million in the long-run scenario.

Table 5. Welfare Gains and Losses

[15] The supply of the avocado endowment factor is used because it determines the overall level of avocado production in a given region. Also, by definition, producer surplus is based on the concept of a specific factor of production.

	Short-Run			Long-Run		
	Welfare Effect	Mean	Std Dev	Welfare Effect	Mean	Std Dev
			Million Dollars			
Changes in Producer Surplus						
California	-$84.49	-$86.88	$16.45	-$9.39	-$9.38	$8.60
Chile	-$8.46	-$9.23	$2.98	$0.55	$0.61	$1.53
Equivalent Variation						
Time Period 1						
Region A	$7.92	$8.31	$1.33	$2.17	$2.24	$0.68
Region B	$24.36	$25.02	$2.19	$15.86	$15.98	$1.27
Region C	$23.80	$24.57	$2.58	$12.89	$13.02	$1.53
Time Period 2						
Region A	$14.70	$14.92	$3.19	$2.54	$2.50	$1.59
Region B	$22.06	$22.36	$4.25	$7.17	$7.14	$2.19
Region C	$22.44	$22.80	$5.21	$1.98	$1.91	$2.77
Net U.S. Welfare Change	$30.78	$31.10	$2.30	$33.22	$33.40	$0.62

The mean and standard deviation columns in table 5 show the results of a sensitivity analysis of the short-run and long-run welfare changes. As with the sensitivity analysis of the quantity and price changes in table 4, the standard deviations for the EV values are small. The standard deviations for the changes in producer surplus are larger, however, implying greater variability. In the sensitivity analysis, the loss in producer surplus for California producers ranged from $65.3 million to $114.2 million in the short-run scenario. In the long-run scenario, the change in producer surplus for California producers ranged from a $23.4 million loss to a $0.4 million gain. (The gain in producer surplus only occurred once out of 15 different simulations.)

Conclusion

This paper has utilized a static, partial equilibrium model with avocados from different sources assumed to be heterogeneous goods to evaluate the economic effects of allowing fresh

Hass avocados from approved orchards in Mexico to be imported into the United States without geographic or seasonal restrictions. Until seven years ago (1997), phytosanitary restrictions precluded entry of Mexican avocados into the conterminous United States. The government of Mexico contended that this ban was not necessary and after several years of exchanges of technical assessments, the ban was partially eased to allow imports into a limited number of northeastern states (and the District of Columbia) during four winter months. The geographic and seasonal restrictions were deemed components of a "systems approach" to pest risk management that also included production, processing and shipping procedures for the approved orchards. Subsequently, the access was extended to 12 additional states and six winter months, with the geographic and seasonal restrictions still viewed as necessary to the systems approach. By 2003, however, based on the success of the limited import program in avoiding pest risks and on additional pest risk analysis, the government of Mexico requested consideration of eliminating the geographic and seasonal restrictions.

The structure of the model utilized in this paper, our approach to modeling increased access with a preference shift, and the scenarios and simulation results presented reflect the recent evolution of access of Mexican Hass avocados to the U.S. market. Without repeating the results, our short-run analysis indicates that expanding access throughout the year to all states would cause a decrease in production and prices for California and Chilean producers, while Mexican exports would increase. Sensitivity analysis indicates that the short-run simulation results vary little for a plausible range of values for the model parameters and exogenous parameters, with the loss in producer surplus being the most sensitive result.

In the long run, we assume that avocado demand increases with income growth and population. These effects dampen the negative impact of increased access on producers in

California and Chile. The loss in producer surplus for Californian producers is a little over one-tenth the size of the welfare loss when population and real income are held constant. While the welfare gain to US consumers is also smaller, due to smaller wholesale price changes, the simulated net welfare gain is slightly larger.

While somewhat stylized in our analysis, demand growth has been an important feature of avocado markets in recent years. Moreover, our preference shift effect does not fully capture the increased demand that may be associated with increased availability of Hass avocados. Thus, the long-run scenario with income and population growth probably gives a better assessment of the avocado production and market situations that would be observed a few years after approved orchards in Mexico received unrestricted geographic and seasonal access to the United States. Regardless of the magnitude of the growth in demand, consumers in the United States will benefit from a greater availability of fresh avocados at lower prices.

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