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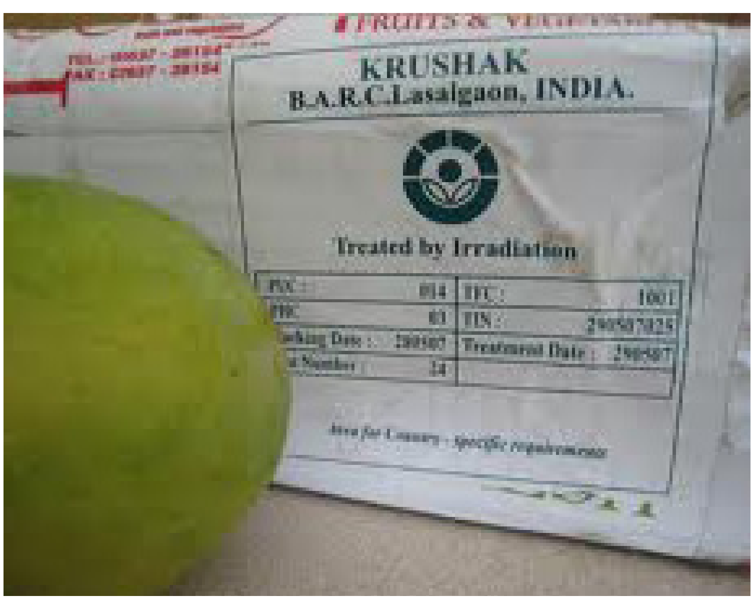

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Abstract

Certain specialty crops produced in other countries have gained better access to U.S. markets since 2007, when USDA's Animal and Plant Health Inspection Service changed its regulatory protocols for phytosanitary (plant health) concerns. One treatment option allowed under the 2007 protocols is irradiation. Using the example of U.S. imports of Indian mangoes, we examine the role of irradiation in mitigating pest risks from imported fresh produce, the costs associated with treating, shipping, and marketing fresh produce imports in the U.S. market, and the resulting increased availability and lower costs of Indian mangoes for U.S. consumers.

Keywords: India, mango, import access, irradiation, phytosanitary treatments

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Contents

Summary

What Is the Issue?

Certain specialty crops produced in other countries, such as Indian mangoes, have gained greater access to U.S. markets since 2007, when USDA's Animal and Plant Health Inspection Service changed its regulatory protocols for ensuring goods are free of pests. One treatment option considered under the 2007 protocols as an effective quarantine measure for neutralizing nearly all insect pests is irradiation. Using the example of U.S. imports of Indian mangoes, we examine the role of irradiation in mitigating pest risks from imported fresh produce; the costs associated with treating, shipping, and marketing fresh produce imports in the U.S. market; and the resulting levels of prices and availability of Indian mangoes for U.S. consumers. (For more information on 2007 regulatory changes, see: http://www.aphis.usda.gov/import_export/plants/plant_imports/index.shtml.)

What Did the Study Find?

Increased access of foreign fresh produce to the U.S. market, facilitated by risk-mitigation options such as irradiation, can improve U.S. consumer welfare. While increased variety and availability of goods are likely to benefit consumers, the size of these benefits depends on whether these goods are able to capture a substantial market share. In the case of U.S. imports of Indian mangoes, India's share of the U.S. market remains small and dependent on the apparent willingness of some consumers to pay high prices for India's mango varieties relative to competing varieties from larger exporters, such as Mexico. Our findings indicate that these high prices arise primarily from transportation costs and high wholesale margins and not from the regulatory or treatment costs.

- Irradiation, a postharvest treatment that neutralizes a wide range of pests, can facilitate access to the U.S. market for fresh produce that may not be able to meet U.S. regulatory requirements by other means. The costs of irradiation are likely to fall if the treatment becomes more commonly used.
- Irradiation and other regulatory compliance costs appear to be low relative to other logistical and marketing costs for fresh produce accessing the U.S. market. Innovation and increased scale that reduce transportation costs and wholesale margins are likely to yield greater gains in imports and result in more imported produce being available to U.S. consumers than are reductions in irradiation costs.
- While the benefits to U.S. consumers of improved availability and lower costs associated with an individual niche product, such as Indian mangoes, may be small, the cumulative gain to U.S. consumers from improved access to a broad range of specialty crops likely would be substantially greater.

How Was the Study Conducted?

This study uses a partial equilibrium model of the U.S. and Indian mango markets to estimate the value of increased imports of Indian mangoes arising from changes in costs associated with irradiation treatment, shipping, and wholesale margins. Demand is modeled using a constant elasticity of substitution utility framework, calibrated with trade and price data from USDA's Foreign Agricultural Service and Agricultural Marketing Service, as well as from the U.S. Department of Commerce's Bureau of Economic Analysis and Census Bureau. Costs are modeled using detailed wholesale and retail data provided by the Indian Ministry of Agriculture's Agricultural Marketing Information Network (Agmarknet), as well as cost information obtained through interviews with Indian traders.

Introduction

U.S. demand for fresh fruits and vegetables is increasing and a growing share of U.S. fresh produce comes from developing countries. For these goods, both sanitary and phytosanitary restrictions and logistical factors may act as significant barriers to trade. In the case of phytosanitary restrictions, import access often depends on whether preharvest production practices and postharvest treatments can ensure that goods are pest-free. Since 2007, USDA has certified irradiation treatment as an effective quarantine measure for neutralizing nearly all insect pests. Irradiation, which often is the only postharvest treatment without substantial and difficult-to-verify changes to production and handling systems, may facilitate further growth in U.S. produce imports from developing countries.

After discussing the recent growth in U.S. fresh produce imports, this report examines the pest risks associated with their importation and how irradiation mitigates that risk. Using a case study of Indian mangoes, we first detail the cost structure of this high-cost commodity sold primarily in a niche market. For mangoes from India, transportation costs and wholesale margins within the supply chain are high, and the share of the U.S. wholesale cost attributable to these costs is far larger than the share attributable to irradiation. We quantify the economic benefits of regulatory and logistical changes that reduce the costs associated with importation, including those associated with irradiation for which USDA may have some measure of control. Our findings suggest that the resultant increases in imports of Indian mangoes are small relative to the broader mango market and that reductions in the costs of irradiation would generate only small welfare benefits for U.S. consumers. Reductions in wholesale margins and shipping costs, however, are shown to have a relatively large impact on imports and consumer welfare.

U.S. Imports of Fresh Produce and Sanitary/Phytosanitary Treatments

Fresh fruit and vegetable imports are growing. Between 2000 and 2008, the import value for edible fruits and vegetables grew more than 8 percent annually, and by 2008, these goods accounted for about 15 percent of U.S. agricultural imports (Economic Research Service, 2010). A large and increasing share of fruits and vegetables is being supplied by developing countries (table 1).

Developing countries that have not historically shipped goods to the United States must address potential pest problems before they can access the U.S. market. Often, these countries have unique pest species, different climates, and weaker institutional and enforcement capabilities to implement mitigation strategies.

Imported fruits and vegetables may carry invasive species that are not indigenous to the United States. While there is some uncertainty about the magnitude of the threats associated with a specific good or pest, the aggregate damage of invasive species is generally understood to be quite large (see box, "The Cost of Invasive Species").

For this reason, in most cases, fresh fruit and vegetable imports are inspected for pests. Imports suspected of carrying pests must receive a risk-mitigating treatment. If a treatment is not feasible, the goods are either shipped to another country without a quarantine requirement, returned to their country of origin, or destroyed. Treatments that kill, physically remove, or render pests sterile include:

- Mechanical treatments. Produce is shaken, washed, or run through chemical or hot water dips.
- Temperature treatments. Produce is exposed to hot or cold temperatures.

Table 1
U.S. fresh fruit and vegetable imports from developed and developing economies

		Average U.S. imports (Million dollars)			Average shares of the U.S. market (Percent)			Annual growth rates[1] (Percent)	
		1990-92	1999-2001	2007-09	1990-92	1999-2001	2007-09	1992-2001	2001-09
Developing economies	Agricultural products	20,118	27,173	64,714	49	53	64	3.4	11.5
	Fresh fruits	418	828	1,411	26	41	41	7.9	6.9
	Fresh vegetables	77	158	277	10	13	15	8.3	7.2
Developed economies	Agricultural products	20,590	23,928	36,482	51	47	36	1.7	5.4
	Fresh fruits	1,162	1,181	2,014	74	59	59	0.2	6.9
	Fresh vegetables	726	1,016	1,619	90	87	85	3.8	6.0

[1]Growth rates are computed between 3-year averages, ending on the years indicated.
Source: USDA, Foreign Agricultural Service, 2010.

The Cost of Invasive Species

The diverse effects of invasive species on agricultural production and the environment stymie attempts to estimate their aggregate costs. Invasive nonindigenous species can lower crop yields, damage recreation areas, threaten native species, spread disease, encourage wildfire, destroy timber and wildlife resources, or alter ecosystems. Studies by the Government Accountability Office (2003) and the Office of Technology Assessment (1993) estimate that economic loss due to foreign pests and diseases sum to billions of dollars annually and severely affect ecosystem services. Related work estimates that control costs rose twentyfold from $10.4 million to $232 million in the 1990s and that annual comprehensive prevention, control, and monitoring expenditures have increased to over $1 billion in recent years (Livingston and Osteen, 2008; Lynch and Lichtenberg, 2006). Costs associated with specific pests or commodities are easier to estimate, including Livingston's estimates with the Mediterranean fruit fly (2007); Cook's with grape pests (2007); Cook et al.'s with the varroa bee mite (2008); and Petersen and Orden's with the avocado seed weevil (2008).

- Fumigation. Produce is treated with a gas (typically methyl bromide) that kills a broad spectrum of insects.
- Irradiation. Produce is irradiated with radiant energy, which at certain intensities disrupts cellular activity in insect pests, rendering them incapable of reproducing.

Each treatment has drawbacks. Mechanical treatments do not work on all pests. Fumigation harms some commodities and fails to kill pests that burrow into the fruit or vegetable. Additionally, the primary fumigant used—methyl bromide—is an ozone-depleting substance for which use is curtailed by the Montreal Protocol (Ferrier, 2010). When mechanical treatments or fumigation are impractical, irradiation can typically treat insect pests without affecting the quality of most commodities. As a single postharvest measure, irradiation does not require monitoring of multiple production, shipping, and handling practices, as might be required under a systems-approach protocol (Follett and Neven, 2005). Irradiation, however, is more expensive than other treatments, requires specialized packaging and labeling, and, like mechanical treatments, generally must be performed prior to shipping (see box, "The Logistics of Handling Irradiated Fruits and Vegetables"). Estimates suggest that an irradiation treatment of peaches, apples, plums, or cherries might cost two to three times that of fumigation, which costs around 1 cent per pound of product treated (Ferrier, 2010, Forsythe and Evangelou, 1994).

Like other treatments, irradiation affects the quality of certain commodities in varying degrees. Some foods lose firmness, some ripen quicker, and some may develop spots. Some byproducts may be released and vitamin C content may fall when the irradiation dose is high—effects comparable to cooking (Fan and Sokorai, 2008). The dose of irradiation needed for quarantine purposes is low, compared with other applications, such as neutralizing foodborne bacteria. For instance, neutralizing *E. coli* O157:H7 in spinach requires an irradiation dose exceeding 2,000 grays—the unit of measure for imparted

The Logistics of Handling Irradiated Fruits and Vegetables

Unlike methyl bromide fumigation, irradiation requires specialized facilities, necessitates logistical changes and product labeling, and is highly regulated. The actual irradiation dose is generated in two ways; by electricity (X-ray or E-beam) or by radioactive material (cesium or cobalt). With either method, thick shielding walls confine the radiation to a designated area. Irradiating fruits, vegetables, or other products requires simply moving the products past the irradiation source by conveyor belt. To increase the dose, the time of exposure to the irradiation source is lengthened by slowing the conveyor belt.

When plant tissue and packing boxes are irradiated, the exterior portions absorb a higher dose and the interior portions a lower dose. Currently, the U.S. Food and Drug Administration regulations forbid fruits and vegetables (with the exception of leafy greens) from receiving an absorbed dose of more than 1,000 grays. USDA's Animal and Plant Health Inspection Service requires the boxes to be relatively small and irradiation of whole pallets is typically infeasible. Also, boxes must be unaffected by irradiation. Finally, because (sterile) irradiated insects are indistinguishable from untreated ones, boxes must be wrapped in plastic before shipping to prevent the re-entry of new pests during transit.

irradiation. Mitigating most insects[1] requires a dose of only 400 grays. The 400-grays level is considered a generic treatment for most insects regardless of their species. But some commodities carrying only specific chronic pests of quarantine concern, such as the Mediterranean fruit fly, can be treated effectively with lower levels of irradiation.

In addition to pest mitigation, irradiation is used to improve food safety and prolong shelf life. But, despite widespread regulatory approval of irradiation, only a small portion of consumer goods are currently irradiated. This is most likely due to the process' relatively high cost and negative consumer perceptions (Ferrier, 2010). Ferrier notes that only about a third of spices imported into the United States are irradiated; spices are not required to be labeled as irradiated if they are further processed (see box, "The Labeling of Irradiated Products"). Despite having longstanding regulatory approval and substantial private investment, irradiated goods represent less than 1 percent of meats or fish consumed in the United States.

Regulatory approval of irradiation as a quarantine treatment has been in place since 2001, when Hawaii was allowed to use irradiation on Hawaii-produced goods shipped to the mainland United States. Since 2006, the treatment has been used by international trade partners. Ferrier (2011) shows that irradiation is making small inroads to U.S. markets for tropical, specialty foods (i.e., guava, mango, longan, and dragon fruit (also known as pitahaya)) that have few domestic or other permitted sources. Often, these products are favored by ethnic communities who are willing to pay markups for their purchase (Roy, 2009). The irradiation treatment may become more common as: the

[1]Excluding a specific order of moths and butterflies.

The Labeling of Irradiated Products

The U.S. Food and Drug Administration requires that irradiated goods bear the radura logo. Unprocessed foods, such as whole fruits, must retain this logo when displayed for sale. Processed foods, such as sauces or ingredients in cooked foods, do not require a label. For example, irradiated nutmeg does not require the radura label if used as an ingredient in eggnog. The same spice would require a label if sold alone on a supermarket shelf. About a third of spices consumed in the United States are irradiated.

Retailers generally wish to avoid having to put the radura logo on retail foods because the logo is perceived negatively by consumers. But when consumers believe irradiation improves food safety, Fox et al. (2002) show that consumers not only perceive the radura logo positively, but are willing to pay a premium for irradiated food. These consumers, however, remain sensitive to new, negative information on the effects of irradiation, regardless of source, scientific rigor, or veracity. Related research suggests that consumers may be as sensitive to information provided by activists as by scientific experts (Hayes et al., 2002). Still other research confirms the negative perception of irradiation among some consumers (Parkhurst et al., 2004). FDA is currently (as of September 2012) considering revising labeling regulation to allow for supplemental information to be added to the radura label and removing the requirement for spices to include the radura label (FDA, 2007).

import permit process is streamlined to allow irradiation's use as a generic treatment for most insect pests; the treatment is approved in more applications; labeling regulations for irradiation use are changed; and alternative treatments, such as methyl bromide fumigation, become less available.

While fumigation and mechanical treatments remain available, however, irradiation likely will be used only in limited circumstances when market access is otherwise impossible. For instance, several species of fruit fly, including the Mediterranean fruit fly, are endemic to areas where melons and citrus are produced. While Spanish citrus can withstand extended cold treatment for the fruit fly, guava, mango, and papaya cannot. The high cost of building an irradiator for export solely for the U.S. market[2] may only be justified if the U.S. market is underserved and has relatively high prices. Bananas, pineapples, and grapes offer slim profit margins and are likely to be poor candidates for irradiation. On the other hand, niche goods like mangoes and dragon fruit may earn high prices on the U.S. market that justify exporters' expenses.

[2]Few countries, with the exception of New Zealand and Australia, also currently import irradiated goods though this situation may change if reciprocity agreements obligate exporting countries to allow irradiated imports as a condition to exporting them.

The Case Study of Indian Mangoes

The United States is the world's largest market for imported fresh mangoes, a market that is served primarily by Mexico and an array of smaller Central and South America suppliers. India is the world's largest mango producer, accounting for more than 40 percent of global output, and the world's largest exporter, just ahead of Mexico. Indian mango exports to the United States were halted by USDA's Animal and Plant Health Inspection Service (APHIS) in the mid-1980s because of concerns about pesticide residues. Access was reopened in 2007 under a bilateral agreement that requires, among other things, irradiation of the mangoes under APHIS inspection to mitigate pest risk (Kavilanz, 2007). Exports resumed in 2007 and, through 2009, India was the ninth-largest U.S. supplier (*World Trade Atlas*, 2011). However, relative to Indian domestic production, exports were negligible, at just 210 tons. Moreover, the 183,000 tons Mexico annually ships to the United States dwarfs India's exports to the United States (U.S. Department of Commerce, U.S. Census Bureau, 2011).

The potential pest risks of Indian mangoes are outlined in the 2006 APHIS qualitative pest risk assessment (PRA) (see box, "The Pest Risk Assessment for Indian Mangoes"). To mitigate these risks, Indian mangoes must undergo several treatments and inspections before they enter the United States, including: an irradiation treatment with a minimum absorbed dose of 400 grays to treat insect pests; inspection and fungicidal treatments for fungal pests; and preclearance inspection within India for bacterial pests.

The U.S. Market for Fresh Mangoes

Since 1998, the United States has reported no domestic mango production, so the market is supplied entirely by imports (table 2). Per-capita consumption increased from 1.49 pounds in 1998 to 2.10 pounds in 2007. But, except for 2005, per-capita consumption remained fairly constant between 2003 and 2007, ranging between 2.01 and 2.10 pounds per year.

Mexico is the largest exporter of fresh mangoes to the United States, accounting for approximately 65 percent of all U.S. imports between 2008 and 2010 (table 3). Brazil, Ecuador, and Peru each provided 8-10 percent

The Pest Risk Assessment for Indian Mangoes

When USDA/APHIS considered whether mangoes could be imported to the United States from India, it conducted a pest risk assessment that documented the risks posed by each potential pest and its potential mitigation mechanisms. Low-risk pests did not require specific mitigation measures, other than inspection. Medium- and high-risk pests required specific mitigation and treatment measures which, in this case, included irradiation. The high-risk pests included seven varieties of fruit flies and one scale insect, while the medium-risk pests included two mango weevils, one scale insect, and three bacterial or fungal pathogens. The low-risk pests and three of the medium-risk scale insects were deemed to have a low likelihood of introduction and establishment in the United States.

Table 2

U.S. imports, exports, and consumption of mangoes

Year	Imports	Exports	Total	Consumption per capita
	----------*Million pounds*----------			*Pounds*
1998	435	23	412	1.49
1999	483	30	453	1.62
2000	518	23	495	1.75
2001	525	15	510	1.79
2002	581	12	569	1.97
2003	614	14	599	2.06
2004	609	17	592	2.01
2005	575	18	557	1.88
2006	645	17	628	2.10
2007	651	16	635	2.11
2008	656	15	641	2.11
2009	634	13	621	2.02
2010	707	14	692	2.23

Source: USDA, Economic Research Service, 2010.

Table 3

Mango production and trade data for major suppliers to the U.S. market

Country	Production	Total exports	Exports/ production	Exports to U.S./exports	Exports to U.S.		
	2008				2008	2009	2010
	1,000 tons		*Percent*		*1,000 tons*		
Mexico	1,937	226	12	80	181.6	184.2	215.5
Ecuador	157	35	22	71	24.7	35.3	25.6
Peru	323	83	26	46	38.2	17.3	32.2
Brazil	1,155	134	12	19	25.7	23.2	24.4
Guatemala	111	20	18	73	14.9	14.7	12.7
Haiti	295	8	3	100	8.3	9.0	6.5
Nicaragua	NA	4	NA	58	2.2	2.4	2.1
Costa Rica	50	9	18	14	1.2	0.9	1.1
India	13,649	275	2	0	0.3	0.2	0.3
Dominican Republic	170	5	3	4	0.2	0.2	0.2
Country total	17,847	798	4	37	297.3	287.3	320.5
World total	34,889	1,195	3	25	297.5	287.4	320.6

NA = Data not available.

Sources: United Nations, Food and Agriculture Organization, FAOSTAT, 2008; Global Trade Information Services, 2009 and 2010.

of U.S. imports between 2008 and 2010, while Guatemala and Haiti each supplied 3-5 percent. Aside from these major suppliers, an array of smaller exporters, including Nicaragua, Costa Rica, and India, accounted for the remaining U.S. imports. Fresh mango imports and consumption show a distinct seasonal pattern, with peak monthly imports averaging about 38,000 tons during April-July and about 14,000 tons during September-February.

U.S. mango prices vary significantly by origin and destination. USDA wholesale price data for fresh mangoes are summarized in table 4 (USDA, Agricultural Marketing Service, 2008).[3] Fresh mangoes from Haiti generally have the highest wholesale price across regions, while mangoes from Guatemala generally have the lowest. These rankings are consistent with the rankings reflected in trade prices. The USDA wholesale price data include few observations for Indian mangoes, but the available data show that Indian mangoes sell at a substantial premium relative to mangoes from other countries.

[3]USDA provides mango price data for 14 U.S. markets: Atlanta, Baltimore, Boston, Chicago, Dallas, Detroit, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco, Seattle, and St. Louis.

The Indian Mango Market

India is the world's largest producer and consumer of mangoes, now accounting for about 40 percent of global production and disappearance.[4] Indian domestic production and consumption vary with annual growing conditions, but grew about 3 percent annually between 2000 and 2010 (table 5). Mangoes are produced throughout the country, with States in all regions contributing significantly to total output. Throughout India, production is highly seasonal, with market arrivals beginning as early as March, peaking during May-June, and ending in August. More than 100 varieties are cultivated, with roughly 20 identified as being commercially significant by India's National Horticulture Board. Prominent commercial varieties include Alphonso (Happus) and Kesar (or Keshar), both important export varieties due to their taste and shelf life, as well as varieties, such as Bangalora (Totapuri), Dashehari, and Langra, that are well known in India and have export potential. India is the world's largest exporter of fresh mango products, exporting an average of about 420,000 tons of mango products annually during 2007-09, including about 73,000 tons of fresh and sliced mangoes and 347,000 tons of mango pulp. Exports of mango products have been growing along with production at about 3 percent annually, but account for

[4]Disappearance data measure the quantity of farm produce that is removed (i.e., "disappears") from farms and is destined for human consumption. Because some farm production is lost in waste and processing, disappearance data typically overstate consumption. If loss rates are stable, however, prices adjust accordingly so that disappearance data can be used in welfare analysis.

Table 4
U.S. wholesale prices of fresh mangoes, by supply region

Exporter	Year 2004	2005	2006	2007	Average 2006-07
	Dollars per carton[1]				
Brazil	6.77	6.94	7.97	7.94	7.96
Ecuador	6.12	5.59	6.85	6.89	6.87
Guatemala	5.81	5.33	5.39	5.57	5.49
Haiti	7.54	8.31	8.82	9.22	9.03
Mexico	4.90	5.95	5.88	5.97	5.92
Peru	5.73	5.31	5.65	7.65	6.68

[1]Prices are for 1-layer flats or cartons, the most common packing.

Source: USDA, Agricultural Marketing Service, 2008.

Table 5
Supply and use of fresh mangoes in India

Marketing year	Production	Exports			Consumption
		Pulp	Fresh	Total	
	1,000 metric tons				
2003/04	11,490	162	47	209	11,281
2004/05	11,830	188	53	241	11,589
2005/06	12,658	259	70	329	12,329
2006/07	13,734	309	80	389	13,345
2007/08	13,997	340	54	394	13,603
2008/09	12,750	367	81	448	12,302
2009/10	13,557	353	75	427	13,130

Source: Government of India, National Horticulture Board; Government of India, Ministry of Commerce and Industry, via *World Trade Atlas*.

only 3-4 percent of domestic supplies. Exports of fresh mangoes account for approximately 0.6 percent of India's mango production. India's major export markets for fresh mangoes are primarily in neighboring areas of South Asia, the Middle East, and Southeast Asia, but also include more distant markets, such as the United Kingdom[5] and, more recently, the United States (table 6). Fresh mango exports to the United States averaged about 165 tons per year between 2007 and 2009, following the 2007 reopening of the U.S. market.[6]

India produces multiple commercial varieties of mangoes, with many varieties marketed primarily in the regions where they are grown. Data on the maximum wholesale price of the Alphonso and Kesar varieties suggest that the domestic markets for these two export varieties are not closely integrated and the simple correlation coefficient of the two varieties' April through June prices in table 7 is just 25 percent. However, because the Alphonso variety has broad national consumer appeal in India and is the major variety produced and exported, we use this variety as our measure of wholesale costs. Because the United States imports only a small proportion of Indian production, and because irradiation capacity does not appear to be a constraint, we assume that the export supply of fresh mangoes from India to the United States is perfectly elastic.

The Cost Buildup for Indian Mangoes Supplied to the U.S. Market

The benefit to both Indian producers and U.S. consumers from access to the U.S. market depends primarily on how effectively Indian mangoes compete with mangoes from other suppliers. The available information for the April-July season during 2007-09, which is a mix of officially reported data and analyst judgment, indicates that Indian mangoes destined for the U.S. market incur significant costs between the farm gate and U.S. wholesale markets (table 8). Within the Indian market, the producer price averages about 27 percent of the export price for Alphonso mangoes. Irradiation charges account for about 20-40 percent of the difference between export and farm-gate prices, with the

[5]Unlike the United States, the United Kingdom's Department of Environment, Food, and Rural Affairs does not require extensive treatment of Indian mangoes, likely because the climate of the UK prevents the mango's pests from becoming established. Subsequently, Indian mangoes have sometimes been transshipped between these countries to disguise their restricted origin (Ferrier, 2010)

[6]The calendar data reported by the *World Trade Atlas* for Indian exports of fresh mangoes to the United States indicate average shipments of 165 tons between 2007 and 2009, while U.S imports from India are reported to average 210 tons. The analysis of economic impacts is based on U.S. import data.

Table 6
Indian exports of fresh mangoes, by major destinations

Destination country	2003	2004	2005	2006	2007	2008	2009	2010	2011
					Tons				
Bangladesh	10,697	35,372	32,587	42,549	16,995	44,538	34,416	23,007	27,597
United Arab Emirates	19,041	8,571	26,704	23,304	22,367	23,338	25,164	28,624	21,917
Nepal	2,418	2,697	4,045	7,927	7,359	4,592	4,243	1,979	3,939
United Kingdom	1,486	1,124	698	2,154	2,531	2,471	2,929	2,841	2,523
Saudi Arabia	3,752	1,747	2,125	1,165	1,720	1,928	3,181	1,745	2,404
Bahrain	503	902	683	487	445	1,137	1,115	1,156	628
Kuwait	349	312	138	320	549	495	783	662	600
Malaysia	255	185	283	273	472	311	415	398	353
Singapore	238	150	249	231	341	290	371	394	584
Qatar	195	183	54	81	51	265	443	615	693
United States	460[1]	207[1]	73[1]	12	136	203	156	119	390
World total	43,722	53,319	70,260	80,252	54,279	81,199	74,652	63,002	63,118

[1]Positive imports to the United States in 2006 may reflect transshipping, importation of processed mangoes, or inaccuracies in data reporting.

Source: Government of India, Ministry of Commerce and Industry, via *World Trade Atlas*.

Table 7
Monthly average maximum wholesale prices for Alphonso and Kesar variety mangoes in India

	March	April	May	June	July
		Rupees per kilogram[1]			
Alphonso					
2005	56	26	24	25	13
2006	55	37	31	18	--
2007	95	48	22	23	16
2008	99	54	51	22	--
2009	70	31	28	23	--
2010	76	65	43	33	30
Kesar					
2005	30	25	13	10	5
2006	--	16	11	11	--
2007	11	24	18	21	17
2008	--	22	17	11	11
2009	18	18	27	28	--
2010	36	22	16	23	43

[1]During time period stated here, conversion rate: 1 U.S. dollar = 43.79 rupees.
-- = not quoted.

Source: Government of India, Ministry of Agriculture, Agricultural Marketing Information Network (Agmarknet).

Table 8

India-U.S. trade price buildup for Alphonso mangoes

	Cost item	Unit	April	May	June	July
			2007-09 (average)			
A.	**In India**					
1.	Farmgate price (unweighted Agmarknet prices)[1]	*Rs/kg*	44.20	33.72	22.68	10.91
2.	Transport from farm to pack house[2]	*Rs/kg*	2.00	2.00	2.00	2.00
3.	Pack house processing and fungicide[2]	*Rs/kg*	5.00	5.00	5.00	5.00
4.	Transport to irradiation plant[2]	*Rs/kg*	1.00	1.00	1.00	1.00
5.	Irradiation and handling[3]	*Rs/kg*	7.00	7.00	7.00	7.00
6.	APHIS inspection fees[4]	*Rs/kg*	34.07	34.07	34.07	34.07
7.	Irradiation plant construction cost[5]	*Rs/kg*	5.14	5.14	5.14	5.14
8.	Transport to Mumbai Airport[6]	*Rs/kg*	1.00	1.00	1.00	1.00
9.	Airport clearing charges[6]	*Rs/kg*	1.00	1.00	1.00	1.00
10.	*Exporter margin (residual; A.11-(A.1:A.9))*	*Rs/kg*	84.24	21.95	-25.49	-9.49
	percent of farm-gate price	*Percent*	190.6	65.1	-112.4	-87.0
11.	Export price (C.1. - B.)	*Rs/kg*	184.65	111.89	53.40	57.62
B.	**Air freight to United States[7]**	*Rs/kg*	119.81	119.81	119.81	119.81
C.	**In United States**					
1.	Import price (C.3 x C.2)	*Rs/kg*	304.46	231.70	173.21	177.44
2.	Exchange rate[8]	*Rs/$*	43.99	43.71	43.68	43.82
3.	Import price[9]	*$/kg*	6.92	5.30	3.97	4.05
4.	Tariff	*$/kg*	0.07	0.07	0.07	0.07
5.	Import price (C.3+C.4)/2.204622)	*$/lb*	3.17	2.43	1.83	1.87
6.	Airport clearance and handling	*$/lb*	NA	NA	NA	NA
7.	Transport and handling to wholesale	*$/lb*	NA	NA	NA	NA
8.	*Importer costs and margins (residual; C.9-C.5-7)*	*$/lb*	0.67	1.40	2.01	3.42
	percent of import price	*Percent*	21	58	110	183
9.	Wholesale price[10]	*$/lb*	3.84	3.84	3.84	5.29
10.	Retail costs and margins	*$/lb*	NA	NA	NA	NA
11.	Retail price	*$/lb*	NA	NA	NA	NA

Agmarknet = Government of India, Ministry of Agriculture, Agricultural Marketing Information Network; Rs = rupees; kg = kilograms; $ = U.S. dollars; lb = pound; AMS = USDA, Agricultural Marketing Service; APEDA = Government of India, Agricultural Product Export Development Authority; APHIS = USDA, Animal and Plant Health Inspection Service; c.i.f. = cost, freight, and insurance; NA = No data available.

[1]Unweighted average of all Maharashtra maximum daily wholesale market prices (Agmarknet).
[2]Trade estimate. APEDA estimate for these three items is Rs 8.79/kg.
[3]Trade estimate. APEDA estimate is Rs 6.59/kg.
[4]Assumes annual fee of $150,000 spread over volume of all mangoes shipped to United States (see below).
[5]Assumes Rs120-million facility cost spread over 30 years, with 25-percent allocation to U.S. mango shipments (see below).
[6]Trade estimate. APEDA estimate for these two items is Rs1.83/kg.
[7]APEDA estimate is Rs110/kg for 2007, increased using U.S. producer price index for air freight services.
[8]Period averages (Source: http://fx.sauder.ubc.ca/data.html).
[9]U.S. import unit value from India, all mangoes; adjusted for variety using c.i.f. equivalents of average Indian wholesale prices. No U.S. import data for April 2007 (Source: *World Trade Atlas*).
[10]AMS terminal market average for India origin. No April-May data for 2007. No 2008, 2009, or 2010 data; 2008 estimated using same percent change over 2007 as kesar variety.

Sources: Government of India, Agricultural Marketing Information Network (Agmarknet); USDA, Agricultural Marketing Service; *World Trade Atlas*; Global Trade Information Services.

remaining 60 to 80 percent accounted for by handling costs, port charges, and trader margins.

Most Indian mango shipments to the United States are sent by air freight. The costs of air freight averaged $2.74 per kilogram (kg) (i.e., 119.8 rupees per kg freight cost divided by 43.8 rupees per dollar exchange rate) during the 2007-09 seasons, or about 20 percent more than the Indian export price of Alphonso mangoes, and this explains a large part of the relatively high price for Indian mangoes. Although U.S. wholesale price data for Indian mangoes are sparse, the available data indicate that there are also significant markups between U.S. import prices and wholesale market prices. The average markups between import (cost, insurance, and freight, or c.i.f.) and wholesale prices for the periods of available price data have been about 80 percent of the import price, with only a minor share of the markup accounted for by the fresh mango tariff of 6.6 U.S. cents/kg.

Charges for irradiation treatment for mangoes at the Bhabha Atomic Research Center (BARC) facility in Nasik, Maharashtra—the only facility currently used for irradiating mangoes—may not reflect the costs borne by the Indian export authorities for onsite monitoring and inspections by APHIS personnel. The bilateral agreement required the Government of India to establish an annual $200,000 trust fund to defer these costs. While information on the costs incurred by APHIS and charged to the trust fund is not publicly available, India's Agricultural Product Export Development Authority (APEDA) puts actual costs at about $150,000 per year (ExpressIndia, 2008).

Also, current irradiation treatment charges do not account for the capital cost of building the irradiation facility in Maharashtra, originally built by BARC for research purposes in 2002. The cost of constructing an irradiation facility in India has been estimated at 120 million rupees ($2.5 million) (Rajendran, 2009). At present, the BARC facility appears to be used for only parts of a few months of the year for irradiating mangoes and some other products, including onions. As a relatively nascent technology to facilitate food trade, low capacity-utilization rates are likely to impose high initial unit costs of treatment, at least until the volume of trade expands.

Several cost items are not fully accounted for in the cost buildup tables. Changes in the mode of shipment may be subject to change over time that may significantly affect the competitiveness of Indian mangoes in the U.S. market, as well as the impacts on Indian growers and U.S. consumers. The cost of air freight and importer costs and margins in the United States are the two largest components of the wholesale price of Indian mangoes in the U.S. market. In 2009 and 2010, Indian exporters experimented with containerized sea freight for shipments to the United States to reduce costs. If this mode of transport proves successful, reports indicate that freight costs can be reduced by 45-55 percent (Das, 2009). Such cost reductions would allow substantially lower U.S. import prices for fresh Indian mangoes and, if achieved with freshness and quality comparable with other competitors, could expand market share.

The costs of shipping Indian mangoes to the U.S. market, consisting primarily of the costs of air freight and marketing costs and margins within India, result in the U.S. import price of Indian mangoes being far higher than that of the major U.S. suppliers (table 9). Between 2007 and 2009, U.S. import prices for Indian mangoes averaged about four times those of the next most expensive supplier, and nearly six times the average U.S. import price.

Clearly, with current logistics and costs, Indian mangoes are likely to be confined to a premium niche for U.S. consumers, including South Asians living in the United States who have taste preferences for the Indian varieties. However, cost reductions, through use of sea freight and other efficiencies that may arise from larger volumes of trade, have the potential to make Indian mangoes more cost competitive. Our analytical section develops a framework for estimating the consumer welfare benefits of these cost reductions generated by regulatory changes and improvements in logistics.

Table 9

Comparison of U.S. mango import prices from major suppliers and India

Country	2007	2008	2009
		Dollars per kilogram	
India	3.64	4.13	4.21
Dominican Republic	1.20	0.93	0.83
Haiti	0.88	0.99	1.05
Peru	0.81	0.78	1.28
Brazil	0.77	0.94	0.95
Nicaragua	0.74	0.79	0.73
Mexico	0.63	0.67	0.70
Ecuador	0.64	0.62	0.63
Costa Rica	0.48	0.55	0.61
Guatemala	0.43	0.51	0.62
World	0.66	0.71	0.76

Source: U.S. Department of Commerce, U.S. Census Bureau.

Analytical Approach

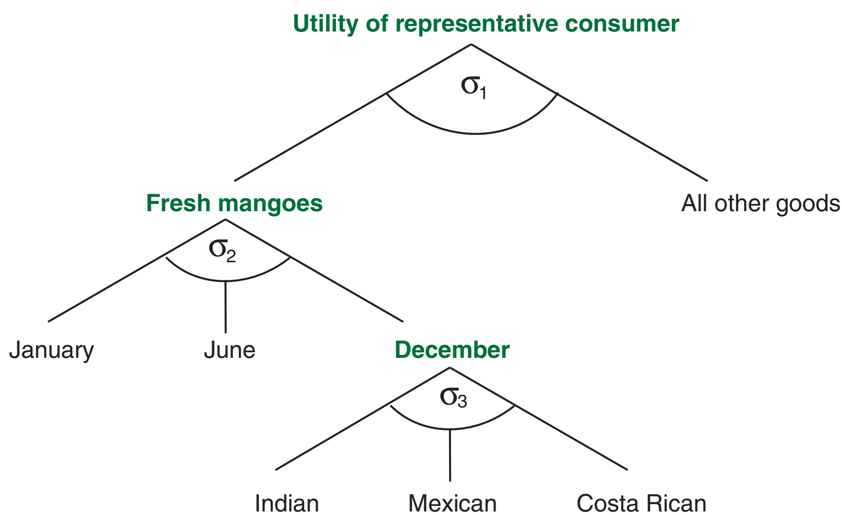
To assess the economic implications of increased Indian mango access to the U.S. market, we explicitly model the costs and benefits involved with the trade in a partial equilibrium model of the U.S. market for mangoes similar to that developed by Peterson and Orden (2008) for avocados. Only the mango market is modeled, and prices in ancillary markets—the wages paid to workers on mango farms, the price of alternate goods that might be consumed instead of mangoes, or the price of other crops that may be produced—are assumed constant. The model and data used are shown in more detail in the appendix.

Consumer Demand

In our analysis of the U.S. market for Indian mangoes, we represent the demand for mangoes and other products as depending on relative prices, where the magnitude of the demand response to price changes is determined by own- and cross-price elasticities of demand. Since empirical estimates may not be available for all own- and cross-price elasticities, the preferences of a representative consumer[7] are represented with a weakly separable, nested constant elasticity of substitution (CES) utility function (fig. 1). In the first stage of consumption, the consumer chooses between mangoes and all other goods. The elasticity of substitution parameter σ_1 estimates how mango demand changes when the relative price between it and the price of all other goods changes. In the second stage, a consumer chooses between consuming mangoes in different seasons. The parameter σ_2 estimates how consumers allocate consumption across seasons in response to changes in the relative price. In the last stage, consumers choose between mangoes from different

[7]By assuming that the elasticity of substitution, which measures the responsiveness of consumer demand to changes in relative prices, is constant across a group of products, one is able to determine all of the own- and cross-price elasticities.

Figure 1
Preference structure for representative consumer



σ_1 = Parameter showing how mango expenditures change as the prices of mangoes relative to the price of all other goods change.
σ_2 = Parameter showing how monthly mango expenditures change as the prices of mangoes change across months.
σ_3 = Parameter showing how expenditures on mangoes from different origins change as the relative price of mangoes across origins changes.

origins. Again, the parameter σ_3 estimates how consumers allocate consumption between mangoes from different origins based on their relative price.

Exporter Supply and Price Linkage

The export supply of fresh mangoes is assumed to be a linear function of the freight on board (f.o.b.) price received by producers in a given region. Because of limited storage opportunities, we assume that producers cannot shift production between months in response to changes in the relative producer prices between months. Thus, only the producer price in the current month will affect export supply.

Estimating the effect of reductions in wholesale costs, transport margins or irradiation costs on import of Indian mangoes requires the specification of the relationship between the wholesale price paid by retailers in the United States and the price received by mango producers abroad. For mango producers outside of India, we assume this relationship is constant in terms of $/kg.[8] For Indian producers, we specify this relationship in terms of the disaggregated costs of shipping mangoes to the United States so that we can later focus on how specific costs change. These costs include the cost of transporting mangoes to the packing house, the cost of processing and fungicide treatment at the packing house, the cost of transportation to the irradiation facility, the cost of irradiation, the cost of transportation to the Mumbai airport, the airport clearing charges, the margin of the Indian exporter, the cost of transportation to the United States, and wholesale margin once goods are in the United States (see table 8). The cost of irradiation includes both a fixed charge (for use of the facility) and per-unit costs as well. The cost of APHIS inspection is assumed to be fixed. Thus, irradiation and inspection include both fixed and per-unit costs so that their average cost falls as Indian exports rise.

[8]The difference between the wholesale and producer price includes such items as transportation and wholesale margins. The size of these margins is determined by the difference between the U.S. wholesale price and the producer price for a given export in a given month. While the magnitudes of the margins may vary across months and exporter, we assume they do not vary across time for the same month and exporter.

Model Data and Parameters

Equilibrium price and quantities from 2007 to 2010 (the base period) are used to implement the model. The United States produces only a trivially small amount of mangoes. Instead, imported quantities, about which information is obtained from USDA's Foreign Agricultural Service (FAS) (2010), represent the market equilibrium quantity. Table 10 lists these values in the column labeled *Base*. Except for Indian shipments, we assume that countries whose imports average less than 250 metric tons (mt) are zero in the initial equilibrium to avoid modeling very small quantity flows.[9] Per capita income is average per capita personal income from 2007 to 2010 (U.S. Department of Commerce, Bureau of Economic Analysis, 2011; U.S. Department of Commerce, U.S. Census Bureau, 2011).

[9]This assumption does not significantly affect the total quantity of mangoes supplied/demanded, reducing the total by 808.8 mt, or 0.3 percent.

U.S. mango wholesale prices (see table 4) are disaggregated by month and averaged from 2007 to 2010 to obtain the average wholesale prices used in the model, and they only reflect the month when a given country ships to the United States. The U.S. wholesale price for Indian mangoes is the average wholesale price of Alphonso mangoes, the main variety exported by India to the U.S. market during the period.

U.S. wholesale margins are the difference between the average c.i.f. price,[10] obtained from FAS trade data, and the U.S. wholesale price. Transport

[10]The c.i.f. price is the price of a good delivered to the frontier of the importing country, including any insurance and freight charges incurred to that point.

Table 10
Results for alternate scenarios for U.S. imports of Indian mangoes

	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Average price	1.5686	1.5680	1.5666	1.5661	1.5616
Dollars per kilogram	(0.0083)	(0.0082)	(0.0080)	(0.0080)	(0.0070)
Total quantity	291.4	291.4	291.6	291.6	292.1
1,000 metric tons	(1.5)	(1.5)	(1.5)	(1.5)	(1.4)
Equivalent variation	N.A.	159.24	576.20	733.45	2021.02
1,000 dollars		(26.9)	(110.2)	(135.5)	(445.8)

N.A. = Not Applicable.

Source: USDA, Economic Research Service simulation.

margins are the difference between the average f.o.b. price and the average c.i.f. price. For all supply regions except India, the producer price is the average f.o.b. price. For India, the producer price is the average price for Alphonso mangoes from 2007 to 2009 (see table 7).

Model parameters from the demand system specification are extrapolated as well as inferred from the available literature. To incorporate sensitivity analysis for our welfare estimates, we use a Monte Carlo method. In this method, we calculate welfare estimates at six values of the model parameters, which are drawn from a uniform distribution around an assumed midpoint. We then present the averages and standard deviations of the model simulations. We assume that the midpoint of the own-price elasticity of demand of mangoes is -0.5 and that the elasticity ranges from -0.25 to -0.75 (Bergtold, et al., 2004, Richards and Patterson, 2003).[11] Because mangoes are perishable and difficult to store, we assume that σ_2 is constant at zero, which implies that monthly mango demand depends only on its wholesale price in each month. We assume that the midpoint of σ_3—the elasticity of substitution between mangoes from different origins—is 1.5 and that it ranges between 1 and 2. The values of all other parameters in the CES utility function are calibrated such that the CES demand function replicates the initial quantities demanded of fresh mangoes.

With no available econometric estimates for the export supply elasticity of fresh mangoes, we assume that the midpoint of η^S (the aggregate import supply for mangoes) is 0.5 and that it ranges between 0.25 and 0.75. Similar produce with biological lags in production, including avocadoes, have comparable production elasticities around 0.4 (Carman and Craft, 1998). Because foreign-produced mangoes can be consumed domestically or shipped to other destinations in addition to being exported to the United States, the export supply elasticity is likely to be larger than the production supply elasticity. In general, as the export share of production decreases, the elasticity of export supply increases. Because India only exports a very small share of its mango production to the United States, we assume that its export supply elasticity is 50. This very large value reflects India's ability to increase exports. More detail on model parameters and model calibration are provided in the Appendix.

[11]Because the CES utility function is homothetic, all income elasticities equal one. However, income is held constant in all model simulations.

Estimated Economic Impacts

We analyze four scenarios for reductions in costs associated with irradiation treatment, transportation, and marketing margins of Indian mangoes. Using the model outlined previously (and detailed in the appendix), we estimate the supply, demand, trade, price, and consumer welfare impacts of each of the following four scenarios:

1. **50-percent reduction in regulatory compliance costs (i.e., irradiation fixed costs and APHIS inspection fees)**. The fixed costs of irradiation and APHIS inspection fees are likely to decrease over time for three reasons. First, inspection protocols may change to allow local staff to oversee the irradiation process, rather than having APHIS staff perform this task as is current practice. Second, irradiation may occur on U.S. soil rather than in India, which might make it cheaper. Third, as larger volumes of goods are irradiated, economies of scale may make it less expensive.

2. **50-percent reduction in cost of shipping Indian mangoes to the United States**. Development of sea freight shipping will lower shipping costs if logistical challenges, such as the need for climate control methods that preserve quality, can be overcome (Bustos-Griffin, et al., 2012).

3. **50-percent reduction in irradiation fixed costs, APHIS inspection fees, and shipping costs**. This scenario combines the previous two scenarios.

4. **50-percent reduction in irradiation fixed costs, APHIS inspection fees, shipping costs, and wholesale margins for Indian mangoes in the United States**. As the trade grows, wholesale margins are likely to fall. Indian mangoes being a “new” product in most U.S. markets means that relatively few retail outlets distribute them. Those outlets may bear a higher cost of promotion and risk.

In all four scenarios, cost reductions lead to lower U.S. wholesale prices for Indian mangoes and increased consumer welfare. The key difference is the cost reduction’s relative size, as it shows the importance of reductions in regulatory and irradiation costs compared with those in transportation or wholesale margins costs. These cost reductions in Indian mangoes also reduce the demand for mangoes from other origins, as consumers substitute the Indian fruit for mangoes from other countries. Our welfare measures account for price reductions that cause consumers to switch between mangoes from different origins. These effects are explained in the Appendix.

In the first scenario, regulatory compliance costs fall, lowering the costs of import compliance. Initially, these costs are $0.895/kilogram[12] (see table 8). A 50-percent reduction lowers this cost to $0.447/kg. As Indian mangoes become relatively less expensive, U.S. consumers substitute Indian mangoes for mangoes from other origins. As Indian mango imports increase, the inspection and facility costs are spread over a large quantity of fruits, reducing the average amount of those costs. This leads to a further $0.033/kg reduction in the cost of compliance and wholesale prices. Overall, Indian exports of fresh mangoes to the United States increase by 8 percent.

[12]Based on the quantity of mangoes exported to the United States from 2007 to 2010, this figure represents the sum of Rs 34.07 (APHIS inspection fee) and Rs 5.14 (fixed operating costs), converted at Rs 43.79 to the dollar.

While the APHIS inspections and irradiation costs are significant at approximately 90 cents/kg, these costs account for only about 10 percent of the U.S. wholesale price. The two largest components of the U.S. wholesale price are wholesale margins and shipping costs and, together, these items account for nearly three-quarters of the wholesale price.

Specifically, air-freighting Indian mangoes to the United States costs an estimated $2.74/kg. This cost is about 10 times greater than the South American transport costs and 40 times greater than the Mexican cost.[13] While the longer distance to India is unavoidable, the reliance on air rather than sea freight likely explains this cost difference. In the second scenario, we assume that the cost of shipping Indian mangoes to the United States falls by half. Holding other factors constant, this reduction decreases the U.S. wholesale price by 15 percent. Moreover, as exports increase, the fixed costs of compliance are spread over a larger export volume than in the first scenario. This leads to an additional 2-percentage-point reduction in the wholesale price of mangoes. Overall, the total price reduction increases imports of Indian mangoes by 31 percent (table 10). Because Indian mango export supply is assumed to be very elastic, most of this benefit is passed onto U.S. consumers as price reductions. The Indian producer price increases by 0.6 percent, compared with a 0.2-percent increase from a reduction in the fixed cost of compliance.

[13]The estimated transport cost of other suppliers is defined as the difference between the c.i.f. and f.o.b. prices.

In the third scenario, both regulatory compliance costs and transport costs fall by 50 percent. These reductions decrease the U.S. wholesale price of Indian mangoes by 21 percent, or approximately $1.95/kg. The compliance and transport cost reductions account for $1.82/kg of the reduction, while the remaining $0.13/kg of this reduction arises from economies of scale associated with the 41-percent increase in exports. Note that the total decrease in the wholesale price in this third scenario is less than the sum of the price decreases in the first two scenarios. This occurs because U.S. consumers not only substitute among mangoes from different origins following the drop in Indian costs, but increase overall consumption relative to all other goods. The movement along the demand curve as increased consumption raises prices and offsets a portion of the cost reduction. Indian producer prices increase by 0.8 percent.

As a niche product, relatively few mangoes are sold, but their wholesale price (i.e., their f.o.b. price relative to their c.i.f. price) is high. Wholesale margins for Indian mangoes are between 3.7 and 6.2 times higher than those of competing suppliers. If Indian mango sales increased substantially, these margins would likely fall.

In the last scenario, we assume that, in addition to reductions in transport and compliance costs, U.S. wholesale margins for Indian mangoes fall by 50 percent. These combined effects show a $2.10/kg drop in the U.S. wholesale price of Indian mangoes. In total, the wholesale price of Indian mangoes falls by 45 percent and exports to the United States more than double, increasing by 136 percent. However, even with this large cost reduction, Indian mangoes still sell for between two-and-a-half and four times more than mangoes from competing suppliers.

For each of the four scenarios, we compute the average equivalent variation—a standard measure of a consumer's economic benefit from a price change.[14] We also compute a standard deviation of the equivalent variation by allowing our assumed supply-and-demand parameters to vary. The standard deviation can be used to create a confidence interval around our estimate of the equivalent variation where the statistical probability is high (e.g., approximately 95 percent) so that the actual equivalent variation lies within two standard deviations of our estimate of the average.

Because Indian mangoes account for only a very small share of total consumption, the average welfare gain—or economic benefit—as measured by the equivalent variation, is small across all four scenarios (see table 10). In the first scenario, lower compliance costs raise welfare by $159,000, with a standard deviation of $27,000. In the second scenario, reduced transport costs raise welfare by $576,000, with a standard deviation of $110,000. In the third scenario, lower compliance costs and transport costs together raise welfare by $735,000, with a standard deviation of $136,000. Finally, in the fourth scenario—lower compliance costs, shipping costs, and wholesale margins—increases welfare by $2,010,000, with a standard deviation of $446,000. While the average equivalent variation is our best estimate of the welfare gain, the small size of the standard deviation relative to the estimated average indicates that the welfare gains from the cost reduction are likely to be positive and close to our estimated average even as we allow for different assumptions about consumer and producer substitution patterns.

[14]The equivalent variation is the income increase (or decrease) needed to make the average consumer indifferent to changes in the cost of compliance, transport, or wholesale margins that raise (or lower) Indian mangoes' prices.

Conclusions

Regulatory change and new risk mitigation options, such as irradiation, could provide U.S. consumers with greater access to niche goods, such as Indian mangoes. While increased variety and availability of goods are likely to benefit consumers, the size of these benefits depends on whether the prices for these goods fall in a manner that allows the goods to capture a substantial market share. Currently, India's share of the imported mango market in the United States is small, despite the apparent willingness of some U.S. consumers to pay high prices. Our findings indicate that these high prices arise primarily from transportation costs and high wholesale margins and not from the regulatory or treatment costs.

Import expansion is, therefore, sensitive to innovations that reduce transportation and wholesale costs. Even large reductions in the costs of treating, shipping, and marketing mangoes to the United States would result in only modest cost drops and increased availability of the fruit for U.S. consumers. However, Indian mangoes represent only a single good from a single origin. When considering the number of niche specialty crops that might be exported to the United States from developing countries generally, the cumulative impact of cost reductions and availability to U.S. consumers could be much greater.

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Appendix

Model Description

To evaluate the effect of cost reduction for Indian mangoes, a partial equilibrium model is constructed, similar to that developed by Peterson and Orden (2008). When Costa Rica and Nicaragua and Ecuador and Peru are aggregated together, seven regions/countries—Costa Rica and Nicaragua (CR-Nic); Ecuador and Peru (Ecu-Peru); Brazil; Guatemala; Haiti; India; and Mexico—supply 99.8 percent of all mangoes exported to the United States (which has very little domestic supply). The model is specified in 12 monthly time periods to capture seasonality.

Despite the lack of U.S. domestic mango production, mango-borne pests from imported fruit can harm other crops once in the United States. Agricultural producers in regions where other crops are susceptible to the insect pests that imported mangoes can carry often oppose the liberalization of phytosanitary trade restrictions because they bear the brunt of any harm that may be caused. Because irradiation treatment, however, mitigates much of the pest risk, we do not identify susceptible and nonsusceptible regions of the United States as previous authors have (Peterson and Orden, 2008).[15]

Prior to the model's development, we tested whether the observed differences in wholesale prices were due to region of origin or to other factors, such as variety and size of fruit. If wholesale price differences are significant after controlling for other factors, then fresh mangoes may be viewed as heterogeneous products, varying by export regions. The analysis of variance (ANOVA) results show how these other factors—city market, region of origin, year, mango variety, package size, and fruit size—affect weekly average wholesale prices (table A1). After controlling for these factors, wholesale prices are significantly different across all regions of origin, except for between Haiti and Peru. Subsequently, we treat them as heterogeneous goods and imperfect substitutes.

Consumer Demand

In this model, the demand for fresh mangoes is derived from a weakly separable, nested CES utility function where a representative consumer is assumed to partition purchases between mangoes and everything else. Mangoes from each region are imperfect substitutes.

We used a preference structure in our analysis (see fig. 1, p. 14).The parameter σ_1 represents the elasticity of substitution between fresh mangoes and all other goods. A decrease in the overall price of mangoes (represented by a price index) relative to all other goods, whose price is assumed to remain constant, would lead the representative consumer to increase his/her consumption of mangoes from all supply regions. To capture the seasonality of the mango supply from different sources, the second stage of the utility function represents monthly mango consumption. The parameter σ_2 represents the elasticity of substitution between mangoes across seasons. Because fresh mangoes are not storable for extended periods, we assume that the elasticity of substitution between months equals zero. A decrease in the prices of mangoes in one month does not directly cause consumers to shift consump-

[15]Margosian et al. (2007) identify areas susceptible to the establishment of the seven *Bactrocera* species in the Indian mango pest-risk assessment. These areas have a risk ranking of 4 or higher on the APHIS scale (which ranges from 1 to 10) and include parts of Alabama, Arizona, Arkansas, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, New Mexico, North Carolina, South Carolina, and Texas.

Appendix table 1

Analysis of variance results for U.S.weekly average wholesale price of mangoes

Variable[1]		Coefficient	Standard error	P-value
Constant		6.89	0.09	0.000
City	Atlanta	-0.71	0.08	0.000
	Baltimore	-0.30	0.08	0.000
	Boston	-0.97	0.07	0.000
	Chicago	-1.47	0.08	0.000
	Dallas	-0.87	0.07	0.000
	Detroit	-0.72	0.07	0.000
	Los Angeles	-1.48	0.07	0.000
	Miami	-1.21	0.08	0.000
	New York	-0.93	0.08	0.000
	Philadelphia	-1.05	0.08	0.000
	Pittsburgh	-0.24	0.10	0.012
	San Francisco	-1.00	0.07	0.000
	Seattle	0.37	0.08	0.000
Country	Brazil	1.17	0.04	0.000
	Ecuador	0.17	0.04	0.000
	Guatemala	-0.49	0.05	0.000
	Haiti	0.58	1.07	0.586
	Mexico	-0.66	0.03	0.000
Year	2004	-0.95	0.03	0.000
	2005	-0.60	0.03	0.000
	2006	-0.23	0.03	0.000
	2007	0.14	0.03	0.000
Variety	Ataulfo	4.11	0.05	0.000
	Francine	2.27	1.07	0.034
	Francis	1.80	1.07	0.091
	Haden	0.18	0.04	0.000
	Keitt	-0.28	0.05	0.000
	Kent	-0.39	0.03	0.000
Package size	4-kilogram container	-0.23	0.04	0.000
	4.5- to 5-kilogram container	0.65	0.11	0.000
	Cartons 1 layer	-0.21	0.03	0.000
	Flats/cartons 1 layer	-0.56	0.08	0.000
Fruit size	7	0.80	0.05	0.000
	8	0.81	0.04	0.000
	9	0.83	0.04	0.000
	10	0.65	0.04	0.000
	12	0.44	0.04	0.000
Number of observations		24,836		
F-value		515.38		0.000
R2		0.43		
Adjusted R2		0.43		

[1]The dropped variables are: St. Louis (city), Peru (country), 2008 (year), Tommy Atkins (variety), flats 1 layer (package size), and 14 (fruit size).
Source: USDA, Agricultural Marketing Service.

tion between individual months. It may, however, indirectly increase consumption in all months by decreasing the overall mango price index. Finally, the parameter σ_3 represents the elasticity of substitution between mangoes from all suppliers in a given month.[16]

Based on the preference structure in figure 1, with *i* indexing the supply region and *t* indexing the month, the uncompensated demand function for fresh mangoes is

$$q_{it} = pop\left[\frac{\alpha_{it}\beta_t\gamma wp_{it}^{-\sigma_3}PI_t^{(\sigma_3-\sigma_2)}PM^{(\sigma_3-\sigma_2)}I}{\gamma PM^{(1-\alpha_2)}+(1-\gamma)}\right] \tag{1}$$

Where

- α_{it} is the preference parameter for mangoes,
- β_t is the preference parameter for mango consumption,
- γ is the preference parameter for aggregate mango consumption (relative to all other goods),
- wp_{it} is the wholesale price of fresh mangoes,
- I is per-capita income, and
- pop is the population.

Note that the price index for all other goods is held constant in the partial equilibrium model and set equal to 1 without any loss of generality, and any change in the mango price index represents a change in relative prices. Thus, it does not appear in the denominator in equation 1.

There are two price indices in the uncompensated demand function in equation 1. The index PI_t is the price index of mangoes defined as

$$PI_t = \left\{\sum_i \alpha_{it} wp_{it}^{1-\sigma_3}\right\}^{\frac{1}{1-\sigma_3}} \tag{2}$$

The index *PM* is the aggregate price index for mangoes and is defined as

$$PM = \left\{\sum_i \beta_t PI_t^{1-\sigma_2}\right\}^{\frac{1}{1-\sigma_2}} \tag{3}$$

Note that when σ_2 equals zero, equation 3 simplifies to

$$PM = \sum_i \beta_t PI_t$$

Export Supply

The export supply of fresh mangoes from all regions is assumed to be a linear function of the f.o.b. price received by producers in that region. Because of perishability, relative price changes in prices between months do not affect

[16]When goods in the model are homogenous and perfect substitutes, the parameter σ_3 equals infinity.

export supply. Subsequently, export supply is a function of the current price only

$$y_{it} = \mu_{it} + \tau_{it} pp_{it} \tag{4}$$

In equation 4, with i indexing the supply region and t indexing the month, y_{it} is the export supply of fresh mangoes, pp_{it} is the f.o.b. price of fresh mangoes, μ_{it} is a model parameter for the intercept term in price relationship and τ_{it} is a model parameter for the slope parameters in the price relationship.

Price Linkage and Market Clearing Equations

The relationship between the wholesale price paid by U.S. consumers and the price received by mango producers is expressed in the price linkage equations. For all suppliers except for India, the wholesale price is defined as

$$wp_{it} = pp_{it} + tmargin_{it} + wmargin_{it} \qquad \forall i \notin India \tag{5}$$

Where

$tmargin_{it}$ is the difference between the c.i.f. and f.o.b. prices of fresh mangoes, and $wmargin_{it}$ is the wholesale margin for mangoes.

Both margins are assumed to be constant for countries other than India. For India, the price linkage equation includes the compliance costs, transportation costs, and Indian exporter margins. Specifically

$$\begin{aligned} wp_{it} &= pp_{it} + packtran + packproc + irradtran + irrad \\ &+ airtran + airclear + expmarg + airfreg + \\ &\frac{(irradfix + inspect)}{\sum_t y_{it}} + wmargin_{it} \qquad \forall i \in India \end{aligned} \tag{6}$$

Where

- *packtran* is the cost (dollars/kilogram) of transporting mangoes to the packing house,
- *packproc* is the cost ($/kg) of processing and fungicide at the packing house,
- *irradtran* is the cost ($/kg) of transportation to the irradiation facility,
- *irrad* is the cost ($/kg) of irradiation,
- *airtran* is the cost ($/kg) of transportation to the Mumbai airport,
- *airclear* is the airport clearing charges ($/kg),
- *expmarg* is the Indian exporter margin ($/kg),
- *airfreg* is the cost ($/kg) of air freight to the United States,
- *irradfix* is a fixed charge ($) for use of the irradiation facility, and
- *inspect* is the cost of APHIS inspection in India ($).

Note that because these last two costs are fixed, their sum is divided by the total quantity of mangoes exported to the United States to determine the cost per kilogram. So as Indian exports to the United States expand, this average cost decreases.

The market clearing equations is formally specified as

$$y_{it} = q_{it} \tag{7}$$

Welfare Measures

Our measure of the welfare benefit to U.S. consumers is the equivalent variation (EV). The EV is the amount of income consumers would need to be paid, while retaining the initial level of prices to reach an equivalent level as they would from a price change. Formally, the equivalent variation is defined as

$$EV = e\left(p^0, u^1\right) - e\left(p^0, u^0\right) \tag{8}$$

Where *e* is the expenditure function, p^0 is initial prices, u^0 is the base level of utility, and u^1 is the level of utility after a price change. Because the CES utility function for the representative consumer is homothetic, the expenditure function is a linear function of utility. Thus, equation 8 can be rewritten as

$$EV = pop \times e(p^0)(u^1 - u^0) \tag{9}$$

Because the expenditure function is for a representative consumer, it can be multiplied by the population to obtain the total level of EV.

The unit expenditure function for the CES utility function, *e(p)*, depicted in equation 1, can be expressed as

$$e\left(p\right) = \left[\gamma PM^{1-\sigma_1} + \left(1-\gamma\right)\right]^{\frac{1}{1-\sigma_1}} \tag{10}$$

Where *PM* is the aggregate mango price index as defined in equation 3. The base level of utility (u^0) and the level of utility after a change in policy or margin(u^1)are computed from the indirect utility function, specified as

$$u = \left[\gamma PM^{1-\sigma_1} + \left(1-\gamma\right)\right]^{\frac{1}{\sigma_1-1}} \times I \tag{11}$$

The parameters in the export supply-and-demand equations are chosen such that the model will replicate the initial prices and quantities. We draw on available literature for the magnitudes of the demand-and-export supply elasticities for mangoes in the model.

Demand Calibration

To incorporate the sensitivity analysis into our model, we generate random values of the parameters σ_1, σ_3, and η^S (the supply elasticity), calculate our welfare estimate at each value of the parameters, and then present the average results and standard deviations for the welfare estimates. Our parameters-generation procedure uses symmetric order three Gaussian quadratures. Following Stroud (1957) and Arndt and Hertel (1997), this requires that we draw six sets of parameters from a symmetric uniform distribution with specific endpoints, or in our case independent uniform distributions.[17] We draw on existing literature to provide the assumed midpoint and endpoints for our distributions of σ_1, σ_3, and η^S.

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

You et al. (1996) and Richards and Patterson (2003) both estimate that the own-price demand elasticity for fresh fruits and vegetables in the United States is approximately -0.4. However, the elasticity of demand tends to be smaller for aggregate product categories (in absolute value terms) than for more disaggregate product categories (Bergtold, et al., 2004). Moreover, demand is likely to be more elastic when the product is a smaller share of consumer expenditure. Fresh mango consumption accounts for approximately 1.5 percent of total fresh fruit consumption in the United States (Economic Research Service, 2010) and, for these reasons, we use -0.5 as the midpoint of the own-price demand elasticity, with -0.25 and -0.75 being the endpoints of the distribution.

Because the econometric estimates are based on consumption data aggregated across space and time, we use the estimate of the aggregate demand elasticity to choose the value of σ_1, the elasticity of substitution between fresh mangoes and all other goods. Using the elasticity form of the Slutsky decomposition, the own-price elasticity for mangoes (ε_M) is expressed as a function of its cost share (S_M), the own-price Allen partial elasticity of substitution (σ_{MM}), and the good's income elasticity (η_M). Formally

$$\varepsilon_M = s_M\left(\sigma_{MM} - \eta_M\right) \tag{12}$$

Because the CES preference structure is homothetic, η_M equals 1 for all goods. In addition, the value of σ_{MM} is expressed as

$$\sigma_{MM} = -\sigma_1\left(s_M^{-1} - 1\right) \tag{13}$$

Combining equations 12 and 13 and solving for σ_1 yields

$$\sigma_1 = \frac{-\left(\varepsilon_M + s_M\right)}{1 - s_M} \tag{14}$$

Note that if S_M is relatively small, as with fresh mangoes, then $-\varepsilon_M \approx \sigma_1$.

We use 1.5 as the midpoint of our (uniform) distribution of σ_3, the elasticity of substitution between mango varieties, and assume it ranges between 1 and 2. Because these values of σ_3 exceed σ_1, all mango varieties are net substitutes (given that σ_2 equals zero). With these values of σ_1, σ_2, and σ_3, the values of the shift parameters (α_{it}, βt, and γ) are calculated such that the CES demand functions can replicate the initial quantities demanded of fresh mangoes.

Supply Calibration

No information is available on the export-supply elasticities for fresh mangoes. Based on related work by Carman and Craft (1998), we use 0.5 as the midpoint of our (uniform) distribution of η^S, the supply elasticity, and assume it ranges between 0.25 and 0.75. Those authors find that avocados, another tree fruit, have a production supply elasticity of less than 0.2. However, export supply is likely more elastic than production supply because goods shipped to alternative export destinations or the domestic market can be redirected to the United States in response to a change in prices. Moreover, export supply is likely to be more elastic if the country's share of exports is smaller. For this reason, we assume that India, as the world's largest exporter and producer of mangoes with only a miniscule share of exports being shipped to the United States, has a constant export supply elasticity of 50.

Given the initial producer price, quantity exported, and export supply elasticity (η_i), our calibrated value of τ_{it} is

$$\tau_{it} = \frac{\eta_i y_{it}}{pp_{it}} \qquad (15)$$

Note that we assume that the export supply elasticity is constant across all months for each supplier. Then, using the initial producer price, export quantity, and the calibrated value of $\tau_{it}(\tau_{it}^*)$, the value of μ_{it} is equal to

$$\mu_{it} = y_{it} - \tau_{it}^* pp_{it} \qquad (16)$$

Indian Mango Price Reductions and Supply and Demand by Other Exporters

In the scenarios analyzed, reductions in compliance costs, transport costs, or U.S. wholesale margins lead to lower U.S. wholesale prices for Indian mangoes in a similar way across all scenarios. Results from the first scenario illustrate these effects.

In scenario 1, the compliance costs for Indian mango exporters fall with a reduction in the APHIS inspection fee and the fixed fee to use the irradiation facility. The reduced compliance cost lowers the price of Indian mangoes relative to other suppliers, inducing U.S. consumers to substitute Indian mangoes for mangoes from other origins during the months that Indian mangoes are available. The reduction in the U.S. wholesale price for Indian mangoes also reduces the monthly price index of mangoes, PI_t, for the months that India exports mangoes to the United States. As shown in equation 2, the magnitude of the reduction in PI_t depends on relative magnitudes of the parameter α_{it}. Higher consumption of Indian mangoes implies a larger value of α_{it} for India and a larger decrease in PI_t. Since May and June have the largest exports of Indian mangoes, these months have the largest decrease in PI_t of approximately 0.2 to 0.3 percent in both demand regions. Because it is assumed that consumers do not shift mango consumption across months as relative prices change (e.g., $\sigma_2 = 0$), the changes in PI_t across months do not directly lead to changes in seasonal mango consumption.

Like the reduction in the wholesale price of Indian mangoes, the reduction in PI_t for April-July reduces the aggregate mango price index, *PM*. Also like the monthly price index, the months with larger overall mango consumption will have the largest values of β_t and thus will have the largest impact on the value of *PM*, as shown in equation 3. Because the period between April and July has the largest consumption of fresh mangoes, the reduction in PI_t for those months results in a reduction in *PM*. This implies that mangoes are now relatively less expensive and U.S. consumers substitute mangoes for "all other goods." Because the nested CES utility function is homothetic, the expansion in mango consumption increases monthly mango consumption proportionally. In January-March and August-December, this implies increased demand for fresh mangoes from all suppliers. The larger the export supply elasticity of the supplier, the larger the increase in consumption. In April-July, the expansion in mango consumption further increases the demand for Indian mangoes. For the mango suppliers that directly compete with India, whether consumption increases or decreases depends on whether the expansion effect dominated the substitution effect. For the base model parameters, the substitution effect dominates in April-June, but the expansion effect dominates in July. Table A2 gives the changes in mango consumption across months for India and all countries.

The change in U.S. consumer demand also affects mango producers. In the months that India does not export to the United States, the expansion of U.S. consumption increases both wholesale prices and producer prices in all exporting regions. In April-June, the decrease in U.S. consumption for non-Indian suppliers reduces both wholesale and producer prices. The increase in demand for Indian mangoes also increases Indian producer prices. Because all supply regions have months when they do not directly compete with Indian suppliers, the impact on each region's average producer price depends on that region's seasonal production patterns. As table A3 indicates, mango producers in Guatemala, Haiti, and Mexico ship a majority of their exports to the United States in April-June and their average annual prices fall in the months when Indian imports increase.

Appendix table 2

Wholesale and producer prices and quantities of mangoes, by month and origin

Region	Supplier	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Quantity demand (metric tons)												
Susceptible	Brazil			144.1					681.5	2587.0	3537.6	1889.4	
Susceptible	Costa Rica-Nicaragua			479.0	409.4	87.8							
Susceptible	Ecuador-Peru	6390.7	4070.1	2429.9	118.8						933.4	6177.5	5388.9
Susceptible	Guatemala			694.8	2852.3	1763.0	198.8						
Susceptible	Haiti				390.9	602.3	608.7	417.8	142.3				
Susceptible	India				8.4	30.6	45.0	1.6					
Susceptible	Mexico		1326.3	8048.7	11794.2	12638.4	16836.4	14451.5	10382.3	3645.4	320.0		
Nonsusceptible	Brazil			305.0					319.1	4321.6	6262.4	4116.1	
Nonsusceptible	Costa Rica-Nicaragua			1075.6	1000.7	240.2							
Nonsusceptible	Ecuador-Peru	9122.8	6808.8	3074.9	176.1						1192.3	4335.7	5930.0
Nonsusceptible	Guatemala			1006.2	3945.6	3052.6	282.8						
Nonsusceptible	Haiti				1141.8	1912.3	1508.4	913.4	210.1				
Nonsusceptible	India				11.6	42.4	62.3	2.2					
Nonsusceptible	Mexico		1829.4	10106.9	15813.8	19866.8	22448.5	21941.0	15359.3	4212.3	299.8		
	Wholesale price (dollars per kilogram)												
Susceptible	Brazil			1.8					1.9	2.1	1.7	1.5	
Susceptible	Costa Rica-Nicaragua			2.0	1.5	1.2							
Susceptible	Ecuador-Peru	1.4	1.5	1.7	1.5						2.2	1.6	1.4
Susceptible	Guatemala			1.5	1.2	1.2	1.2						
Susceptible	Haiti				2.1	1.9	2.1	1.9	1.9				
Susceptible	India				9.3	9.3	9.3	9.3					
Susceptible	Mexico		2.3	1.8	1.4	1.4	1.4	1.1	1.2	1.2	1.5		
Nonsusceptible	Brazil			1.9					1.9	1.9	1.7	1.4	
Nonsusceptible	Costa Rica-Nicaragua			2.0	1.5	1.3							
Nonsusceptible	Ecuador-Peru	1.5	1.6	1.8	1.4						2.4	1.7	1.5
Nonsusceptible	Guatemala			1.8	1.4	1.3	1.4						
Nonsusceptible	Haiti				2.4	2.2	2.4	2.3	2.3				
Nonsusceptible	India				9.3	9.3	9.3	9.3					
Nonsusceptible	Mexico		2.4	1.9	1.6	1.5	1.6	1.4	1.4	1.3	1.8		
	Producer price (dollars per kilogram)												
	Brazil			1.0					0.9	0.9	0.9	0.9	
	Costa Rica-Nicaragua			0.7	0.7	0.8							
	Ecuador-Peru	0.8	0.9	0.9	1.1						0.8	0.6	0.7
	Guatemala			0.5	0.5	0.6	0.6						
	Haiti				1.0	1.0	1.1	1.0	1.0				
	India				0.6	0.6	0.6	0.6					
	Mexico		0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8		
	Monthly mango price index												
Susceptible	Total	1.4	1.8	1.8	1.4	1.4	1.5	1.2	1.2	1.7	1.8	1.6	1.4
Nonsusceptible	Total	1.5	1.8	1.9	1.6	1.6	1.7	1.5	1.4	1.7	1.8	1.6	1.5

Source: USDA, Economic Research Service simulation.

Appendix table 3

Detailed welfare estimates for four scenarios of cost shifts, by month

	Base				Scenario 1: 50-percent reduction in irradiation fixed costs and APHIS inspection fees				Scenario 2: 50-percent reduction in cost of shipping Indian mangoes to the United States			
	Price ($/kg)		*Quantity (mt)*		*Price ($/kg)*		*Quantity (mt)*		*Price ($/kg)*		*Quantity (mt)*	
	India	All	India	All	India	All	India	All	India	All	India	All
Jan.	NA	1.5	0	15,513.5	NA	1.5	0	15,516.3	NA	1.5	0	15,523.67
Feb.	NA	1.7	0	14,034.6	NA	1.7	0	14,037.1	NA	1.7	0	14,043.57
Mar.	NA	1.9	0	27,365.1	NA	1.9	0	27,370.1	NA	1.9	0	27,383.02
Apr.	9.2	1.5	20	37,663.6	8.8	1.5	21.7	37,662.3	7.7	1.5	26.5	37,659.18
May	9.2	1.5	73	40,236.4	8.8	1.5	78.9	40,213.2	7.7	1.5	96.0	40,153.93
June	9.2	1.6	107.3	41,990.9	8.8	1.6	115.9	41,956.3	7.7	1.6	140.8	41,867.74
July	9.2	1.3	3.8	37,727.5	8.8	1.3	4.1	37,732.5	7.7	1.3	5.0	37,745.5
Aug.	NA	1.3	0	27,094.6	NA	1.3	0	27,099.5	NA	1.3	0	27,112.32
Sept.	NA	1.6	0	14,766.3	NA	1.6	0	14,768.9	NA	1.6	0	14,775.75
Oct.	NA	1.9	0	12,545.5	NA	1.8	0	12,547.7	NA	1.8	0	12,553.59
Nov.	NA	1.6	0	16,518.7	NA	1.6	0	16,521.7	NA	1.6	0	16,529.51
Dec.	NA	1.5	0	11,318.9	NA	1.5	0	11,321.0	NA	1.5	0	11,326.36
Total (standard deviation)	9.3	1.5 (0.0083)	204.1	296,775.6 (1,541.2)	8.8	1.5 (0.0082)	220.7	29,6746.4 (1,535.0)	7.7	1.5 (0.0080)	268.3	29,6674.1 (1,513.2)
Equivalent variation - Average total dollars (standard deviation)					$159.24 (26.9)				$576.20 (110.2)			

	Base				Scenario 3: 50-percent reduction in irradiation fixed costs, APHIS inspection fees, and shipping costs				Scenario 4: 50-percent reduction in irradiation fixed costs, APHIS inspection fees, shipping costs, and wholesale margins for Indian mangoes in the United States			
	Price ($/kg)		Quantity (mt)		Price ($/kg)		Quantity (mt)		Price ($/kg)		Quantity (mt)	
	India	All	India	All	India	All	India	All	India	All	India	All
Jan.	NA	1.5	0	15,513.5	NA	1.5	0	15,526.4	NA	1.5	0	15,549.2
Feb.	NA	1.7	0	14,034.6	NA	1.7	0	14,046.0	NA	1.7	0	14,066.1
Mar.	NA	1.9	0	27,365.1	NA	1.9	0	27,387.9	NA	1.9	0	27,428.1
Apr.	9.3	1.5	20	37,663.6	7.3	1.5	28.4	37,658.2	5.1	1.5	48.8	37,653.1
May	9.3	1.5	73	40,236.4	7.3	1.5	103.1	40,132.1	5.1	1.5	174.6	39,966.5
June	9.3	1.6	107.3	41,990.9	7.3	1.6	151.0	41,835.2	5.1	1.5	254.3	41,588.4
July	9.3	1.3	3.8	37,727.5	7.3	1.3	5.4	37,750.5	5.1	1.3	9.3	37,791.6
Aug.	NA	1.3	0	27,094.6	NA	1.3	0	27,117.2	NA	1.3	0	27,156.9
Sept.	NA	1.6	0	14,766.3	NA	1.6	0	14,778.3	NA	1.6	0	14,799.5
Oct.	NA	1.8	0	12,545.5	NA	1.8	0	12,555.8	NA	1.8	0	12,573.9
Nov.	NA	1.6	0	16,518.7	NA	1.6	0	16,532.5	NA	1.6	0	16,556.7
Dec.	NA	1.5	0	11,318.9	NA	1.5	0	11,328.4	NA	1.5	0	11,345.1
Total (standard deviation)	9.3	1.5 (0.0083)	204.1	296,775.6 (1,541.2)	7.3	1.5 (0.0080)	287.9	296,648.5 (1,507.7)	5.1	1.5 (0.0070)	487.0	296,475.1 (1,422.2)
Equivalent variation - Average total dollars (standard deviation)					$733.45 (135.5)				$ 2,021.02 (445.8)			

Kg = kilogram. Mt = metric ton. NA = data not available. APHIS = USDA, Animal and Plant Health Inspection Service.

Source: USDA, Economic Research Service simulation.