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Welfare Assessment of SPS Standards: An Empirical Study of Indo-US Mango Trade Case

Siddhartha K. Rastogi

Indian Institute of Management-Indore, Indore - 453 331, Madhya Pradesh

Abstract

Sanitary and phytosanitary (SPS) standards under WTO's ambit have gained prominence in recent years. However, due to mostly thin evidence, standards are set at prohibitively high levels, inducing sub-optimal outcomes. One such case is of mango trade between India and USA. The US banned import of Indian mangoes from 1989 to 2006 and permitted it thereafter under strict treatment and inspection standards. This study has examined the impact of various policy options on the two trading partners and has explored if the benefit from a higher standard regime is worth the marginal effort. Welfare impact of mango trade on India and US under four policy options (trade ban, nuclear irradiation, hot water treatment, and free trade) has been estimated using partial equilibrium framework with stylized microeconomic models. The study has suggested that policy choices of both the nations are consistent with their respective payoff estimates. However, if India undertakes to compensate the US for any losses due to an India-favouring policy, both the nations may gain more through trade; thereby, implying that there is social improvement if the gainers can fully compensate the losers and still be better off (Kaldor-Hicks efficient outcome).

Key words: SPS, India-USA trade, mango trade, cost-benefit analysis, microeconomic stylized model

JEL Classification: F13, F14, F51, Q17

Introduction

Agricultural trade has become liberated to a great extent under the General Agreement on Tariff and Trade (GATT) and then under the auspices of World Trade Organization (WTO). However, in recent years, non-tariff barriers (NTBs) have become the focal point of trade negotiations among the trading partners. The WTO member countries have adopted two multilateral agreements to deal with NTBs, namely Agreement on Sanitary and Phytosanitary (SPS) measures and Agreement on Technical Barriers to Trade (TBT). A country can adopt SPS measures to protect human, animal, and plant health and life from the risks arising from invasive species of pests, weeds, disease-causing organisms, and toxins present in the imported foods and/or agricultural products.

According to the agreement, SPS standards are commodity-specific standards backed by scientific evidence and shall be kept at a minimal level. However, near absence of empirical basis and over-cautiousness on technical grounds often result in SPS standards more stringent than necessary. According to Rodriguez *et al.* (2000), under the agreement, a member has the sovereign right to determine the level of protection it deems appropriate against bona fide risks. Thus, SPS agreement also provides a potent tool for prohibiting trade, protectionism, and discrimination among trading partners. Such standards adversely affect the allocative efficiency within the economy and reduce the comparative advantage of the nation. Roberts (2000) asserts that any SPS restriction that increases the price

Email: srastogi@iimidr.ac.in

Table 1. India and USA — Mango production and trade

Year	India			USA		
	Production (tonnes)	Export (tonnes)	Export as share of total production (%)	Production (tonnes)	Import (tonnes)	Import value (million US$)
2000	10,503,500	107,015	1.02	NA	235,098	164.562
2001	10,056,800	94,413	0.94	3,000	237,933	183.540
2002	10,020,200	121,164	1.21	3,000	263,347	153.009
2003	12,733,200	134,110	1.05	2,300	278,421	192.891
2004	11,490,000	60,551	0.53	2,600	276,344	180.351
2005	11,605,200	53,480	0.46	2,800	260,841	169.117
2006	12,663,100	69,606	0.55	3,000	292,376	209.650

Source: India's Data - CMIE Indian Harvest; USA Data - USDA ERS (2008), FAOSTAT

of an imported good is, in effect, a tax on all exports, raising the price of tradable goods and bidding resources away from other industries.

The rationale of SPS agreement emerges from the economic implications that the occurrence of invasive species may entail, if not checked by the SPS agreement. There are four vectors for the spread of invasive species — travel, transport, trade, or tourism. The pertinence of SPS measures has increased with the extent of globalization and the ensuing increase in volumes of international trade and tourism. Margolis (2007) quotes Invasive Species Specialist Group (ISSG) figures to show that the number of invasive aquatic species in Europe only has increased exponentially, as it was 183 only in 100 years from 1800 to 1899, 497 in the next forty years from 1900 to 1939, reached 1611 during subsequent forty years from 1940 to 1979, and then within next 19 years between 1980 and 1998, reached a figure of 2214.

The Case of Mango Trade between India and USA

India ranks first in mango production worldwide, supplying about 40 per cent of world mangoes. With almost two million hectares of area under mango cultivation, it is India's top valued horticultural crop. However, India's mango exports have been about only one percent of the total production (Table 1). This is primarily due to huge domestic demand; however, it is also due to lack of export supply chain, high transport costs, and non-exportable quality of Indian mangoes (Mattoo *et al.*, 2007). Mango export is insignificant even in value terms at less than INR 1.5 billion (30 million US$) for 2006-07 (or approximately INR 18 per kg). On the other hand, US production of mangoes is quite insignificant, not exceeding 3000 tonnes per annum (Table 1).

The top export destinations for Indian mangoes are: United Arab Emirates, Nepal, Bangladesh, United Kingdom, and Saudi Arabia. These markets fetch a much lesser price (Table 2) than the US market, which appears to be a much lucrative market. The US market can potentially fetch Indian suppliers INR 180 to 240 per kilogram, which is explained in detail in the section on dataset construction. USA is world's largest mango importer accounting for 32.7 per cent of the total imports during 2003 to 2005 (Evans, 2008). In 2006, US imported mangoes worth US$ 233 million out of which mangoes worth US$138 million (or about 60 %) were imported from Mexico. The top mango exporters to the US are given in Table 3. USA's own mango production is negligible and concentrated in a small pocket. Florida is the major mango producing state of US with over 80 per cent of US-wide mango production, of which about 80 per cent is produced in Miami-Dade County (Mossler and Crane, 2009).

The US banned import of Indian mango in 1989 on account of the excessive usage of pesticides and fear of invasion of fruit flies and stone weevils. India offered to reduce pesticide levels and offered Hot Water Treatment (HWT) as a viable measure of pest control. In 2006, after prolonged negotiations, US permitted the import of Indian mangoes with nuclear irradiation and strict inspection. The inspection norms were

Table 2. Indian mango export — Top destinations: 2005-06 to 2007-08

Country	2005-06			2006-07			2007-08		
	Quantity (tonnes)	Value (million INR)	INR/kg	Quantity (tonnes)	Value (million INR)	INR/kg	Quantity (tonnes)	Value (million INR)	INR/kg
UAE	26,533	730.4	27.50	22,045	658.1	29.9	22,469	632.1	28.10
UK	839	53.8	64.00	1,883	114.1	60.6	2,575	198.2	76.90
Bangladesh	32,770	276.6	8.40	42,887	399.5	9.3	17,063	159.5	9.40
Nepal	4,116	32.3	7.90	8,055	70.7	8. 8	7,550	63.6	8.40
Saudi Arab	1,564	44.2	28.30	1,323	42.2	31.9	1,488	45.9	30.90

Source: APEDA Trade Junction (2008)

Table 3. Top mango exporters to USA: 2002-2006

(in million US$)

Rank	Country	2002	2003	2004	2005	2006
0	World	163.40	176.14	168.56	195.25	233.05
1	Mexico	82.80	93.07	88.28	107.32	137.98
2	Brazil	28.69	28.37	16.69	18.22	18.90
3	Peru	19.89	16.81	21.19	21.52	23.77
4	Ecuador	10.43	13.70	14.41	13.48	19.03
5	Philippines	5.36	8.83	11.69	16.69	12.50
6	Haiti	5.50	4.48	5.48	7.34	8.65
7	Thailand	3.06	3.43	4.23	4.31	4.63
8	Guatemala	4.79	3.64	2.90	2.67	3.40
9	Nicaragua	1.24	2.01	1.35	1.35	1.74
10	Costa Rica	1.10	1.14	1.07	1.09	1.17

Source: *World Trade Atlas*. Ranking is based on total exports of mangoes by the respective countries to US during 2002 to 2006.

prohibitively strict as inspection in India by the US inspectors increases the cost of mango manifold and renders it uncompetitive (Sen, 2007; Rabinowitz, 2007). Interestingly, except USA and Japan, all other countries accept HWT as the viable and safe treatment.

India has favored HWT as an effective SPS measure that reduces the probability of fruit fly infestation by 80 per cent (OISAT, 2009), which USA refuses as insufficient and also harmful to the taste of mangoes (Mitcham and Yahia, 2009). The process includes de-sapping, washing, immersion in hot water, and fungicide. If coupled with bagging of mango fruit or pre-harvest sanitation treatment, HWT provides a completely fruit fly free crop (Verghese *et al.*, 2006). Initial costs of setting up HWT comes to INR 200 thousand for a life of 8 years, a fraction of irradiation plants with substantially lower operational costs (primary data from Central Institute of Subtropical Horticulture, Kakori, Uttar Pradesh).

In the nuclear irradiation of mangoes, the fruit cartons are exposed to gamma rays for about 10 minutes. After irradiation, the fruit is kept in cold storage for at least a day. The irradiation process delays ripening of the fruit, thereby, increasing its shelf-life by about a week. The process also inactivates fruit flies and stone weevil, the two pests of concern. However, the irradiation process is costly and technically sensitive. An irradiation plant requires an initial investment of approximately INR 100 million with a life of 10 years, in addition to maintenance, safety, and operation costs. HWT, on the other hand, requires very low initial investments and is a simple process. The

Table 4. Matrix for impact of mango trade on India

(US$ per annum)

		USA			
		Trade ban	Nuclear irradiation	Hot water treatment	Free trade
INDIA	Impact on consumers	0,0	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)
	Impact on producers	0,0	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)
	Cost of compliance	0,0	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)
	Total	0,0	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)	(A+B+C), (X+Y+Z)

Table 5. Definitions of payoff arguments

Mango trade policy change: complete ban to full liberalization	Notation
Mango consumer surplus in India	A
Mango producer surplus in India	B
Mango treatment cost in India	C
Mango consumer surplus in USA	X
Mango producer surplus in USA	Y
Mango pest loss & elimination cost in USA	Z

process involves de-sapping of the fruit, washing, immersion in the hot water, fungicide, and washing again before placing the fruit in cold storage for at least a day. Countries in the Middle-East and EU as well as China, UK, Bangladesh etc. accept HWT as an effective treatment against all mango pests.

Estimation for Alternative Scenarios

The US, as an importing nation, has four policy options to choose from: (1) a complete ban on mango trade, which was in application for India between 1989 and 2006; (2) HWT, a policy favoured by India; (3) nuclear irradiation, the policy favoured by US and presently in force; and (4) free trade, a policy regime with minimal or zero SPS standards in place.

The welfare impact of mango trade on both India and the US under the four different policy options has been estimated. The welfare change for a nation is typically measured by the corresponding change in the Marshallian Aggregate Surplus (Mas-Collel *et al.*, 2004), which in simple terms, implies linear summation of producers' surplus, consumers' surplus, and revenue (or cost) to the government. For the purpose of this study, cost to the government has been taken effectively as the cost of compliance of SPS standards (if subsidized, otherwise borne by producers) and the cost of control and elimination of any invasive species with a certain degree of risk. Therefore, the welfare impact of a policy change is defined as the net of consumer surplus, producer surplus, SPS compliance cost for the exporting nation, and control and spill over costs for the importing nation. In addition, the market clearing conditions are imposed.

To summarize, we have tried to complete the game-theoretic bi-matrix of Table 4 with the nearest valid estimation of the national welfare, which has been decomposed into the parts described in Table 5. Please note that the value of the variables is different in every cell, as they emanate from different policy options. Further, some of these variables may take a zero value, if there is no cost or impact associated with that variable. For example, cost of compliance for India (C) would be zero, if there are no SPS standards enforced.

Estimates for Mango Trade — India

The consumer surplus to Indian mango consumers due to export of mangoes to US under different policy options was measured by estimating the Harberger's Triangle (*see* Appendix 1). To measure the consumer surplus, Equation (1) was estimated for different scenarios. The equation can be estimated easily, if the benchmark dataset includes the three required parameters under all the four possible scenarios —

mango demand elasticity of Indian mango consumers, quantity demanded of Indian mangoes, and domestic price of mangoes. With this information, an estimate of consumer surplus of Indian mango consumers under all the four policy options was derived. The consumer surplus under alternative scenarios was compared with that under trade ban scenario for assessing the impact of the policy change.

$$\text{Consumer surplus} = \frac{1}{2} \times \frac{\text{Price}}{\text{Demand elasticity}} \times \text{Quantity} \quad \ldots(1)$$

The quantity traded under different scenarios was arrived at in different ways. According to Agricultural and Processed Food Products' Export Development Authority (APEDA), India is expected to export 8,000-10,000 tonnes of mangoes to the US every year once the trade with nuclear irradiation treatment begins (Business Line, 2007). This provides the expected quantity of exports to the US under irradiation regime. For the expected export quantity under free trade regime, it was assumed that the top quality mangoes that are presently exported to the European or Middle-East countries would be exported to the US, simply due to high prices offered by the US market. This assumption controls for the quality of mangoes as well, which is much inferior in the case of low price exports to Bangladesh and Nepal. As HWT, as a policy, stands somewhere in between the two alternative policy regimes of irradiation and free trade, the expected quantity of export under HWT regime would be somewhere in between the two regimes; hence, a simple average of the export quantity under the two regimes was taken as a fair estimate of the export quantity under HWT regime. Although this assumption is difficult to accept due to lack of theoretical evidence on comparative statistics on HWT and nuclear irradiation, it is based on expectation on the hierarchy of strictness of policy options.

The elasticity estimate (e_d) for the base line scenario was drawn from Mittal (2006), which is the all-India uncompensated elasticity of demand for fruits and vegetables group. Since mango is the largest horticultural crop for India, the number was taken as a close approximation. Further, we treated this estimate as applicable here instead of mangoes only for two reasons; first, mangoes constitute the largest and highest value share in the Indian fruit basket, and; second, this is the closest estimate available for mangoes. Other studies are too broad, more generic, outdated, or all of these, e.g., Islam (1990). As the aim was to capture the change in utility as a result of change in consumption, the Marshallian or uncompensated elasticity of demand was considered. Rest of the demand elasticity estimates were derived by a simple linear approximation with demand elasticity under trade ban regime and HWT regime. The mango demand elasticity estimate under the HWT regime was derived by comparing the total available quantity (Q_2) of consumption to the Indian consumers and the price the Indian consumers pay at the beginning (P_1) and at the end (P_2) of the benchmark period under trade ban scenario. HWT was used for approximation and thereafter for linear extrapolation and interpolation instead of any other policy regime for the elasticity estimate under the remaining two policy regimes, as that was the prevailing policy for all the other countries during the benchmark period.

Prices under different scenarios were worked out by a simple estimation of elasticity of demand equation, where all the values except that of Δp were known. The baseline price (P) was adjusted for inflation with the Consumer Price Index - Industrial Worker (food group) for four months between April to July (RBI, 2009), which are the four months of mango season in India. All these prices are FOB prices, which are the relevant benchmark for the Indian mango producers. The benchmark dataset for different SPS regimes thus compiled has been depicted in Table 6.

The gain to Indian producers was estimated by assessing the value differential between the domestic market and export to the US market. The prevailing domestic price, as depicted in Table 6, under different scenarios was compared with the FOB price the Indian producers would get on exporting to the US. A simple estimation of the value gain to Indian mango-producers under different policy regimes was compared with the baseline scenario and any excess over and above the baseline scenario was assigned as the cumulative producers' gain to India. The estimates for cost of compliance were collected from the facilities directly. HWT and allied costs were collected through visits to Central Institute of Sub-tropical Horticulture (CISH) in Kakori, Uttar Pradesh and two mango pack-house facilities in Kakori and Lucknow, Uttar Pradesh. The irradiation cost estimates were collected from KayBee

Table 6. Benchmark dataset for different SPS regimes: 2004-2006

Year	Trade ban	Irradiation	HWT	Free trade
		Prices (INR/tonne)[a]		
2004	15409	15419	15426	15432
2005	16645	16657	16669	16680
2006	16681	16693	16702	16711
		Quantity (Production + Import – Export)(tonne)[a]		
2004	11,429,449	11,420,449	11,413,939	11,407,430
2005	11,551,758	11,541,758	11,531,070	11,520,382
2006	12,593,494	12,582,494	12,573,263	12,564,031
		Price elasticity[b]		
	0.98	1.169	1.234	1.299

Sources: a) APEDA Trade Junction (2008) and author's calculations.
b) Mittal (2006) and author's calculations.

Exports of Mumbai, Maharashtra, one of India's largest mango exporters to the US. These costs were verified with the figures from APEDA. The cost of irradiation is shown in Tables 7a and 7b and that of HWT in Table 8.

The estimates for all the four scenarios were summed up and averaged for annual estimates after conversion into US$ with relevant exchange rates. The compiled results are shown in Table 9. The trade ban scenario shows all the values as zeros, since all the other numbers are over and above this baseline scenario. Notably, the cost of compliance under free trade was also zero, as there might not be any standards in force under this scenario. Further, Indian suppliers always gain from the access to high premium market of the US. However, Indian consumers also benefit due to overall production rise and probable improvements in quality due to the rush to export to the high premium US market.

Table 7a. Post-harvest irradiation cost estimates for mango

(INR per kg)

Expenditure	APEDA	KayBee Fresh
Transport - Farm to pack house	9	2
Processing at pack house (Fungicide)		5
Pack house to irradiation plant		1
Irradiation + Handling	7	7
Irradiation Plantto Mumbai Airport	2	1
Clearance charges at Mumbai Airport		1
Air-freight to USA	109	110
Total	127	127

Source: Primary data from APEDA, CISH Kakori, Mango Packhouse Kakori, and KayBee Fresh

Table 7b. Other costs for exporting irradiated mangoes to USA

Cost of new plant and facilities	INR 100 million
Life of plant	10 years
Cost of farm certification (once)	US$ 750
Farm infrastructure cost (first year only)	US$ 2,500
Cost of farm inspection (per annum)	US$ 300

Source: Hindu (2008), Bourquin and Thiagarajan (2007)

Table 8. Cost of HWT treatment of mangoes

(INR/kg)

Transport (Farm to Pack-house)	2.00
Pack-house (De-sapping, HWT, Fungicide)	2.50
Cold storage	2.13
Total per kg	6.63
Cost of plant (Life = 8 years)	200,000

Source: CISH Kakori, Mango Packhouse Kakori, and KayBee Fresh

Table 9. Estimates for impact of mango trade on India

(US$ per annum)

Variables	Trade ban	Irradiation	Hot water treatment	Free trade
Impact on consumers	0	376,550,527	532,432,404	682,715,087
Impact on producers	0	46,472,628	46,398,347	34,071,311
Cost of compliance	0	-3,733,295	-2,698,807	0
Total	0	419,289,859	576,131,945	716,786,399

Source: Author's calculations.

Table 10. Indian export as a proportion to total US consumption: 2004-2006

(in per cent)

Year	Trade ban	Irradiation	Hot water treatment	Free trade
2004	0	3.31	5.70	8.10
2005	0	3.90	8.08	12.26
2006	0	3.81	7.01	10.21

Source: USDA ERS (2008) and author's calculations.

The payoff estimates in Table 8 clearly indicate that the most well-paying strategy for India is free trade of mangoes; however, India has been demanding for HWT, perhaps with the view of minimizing the potential loss to US due to mango pests. Since the negotiation strategy of India would depend on not only its own payoff but also on that of US, an estimation exercise for scenario-wise payoff to US follows.

Estimates for Mango Trade — USA

According to APHIS (Federal Register, 2006), permission for mango imports from India would have minimal impact on the US mango producers and the benefits of opening up the market to Indian mangoes would outweigh any expected costs to the US domestic producers. Going by the conservative principle, we estimated the impact on US producers by assigning proportionate loss of market to them. For example, if Indian mangoes acquire 10 per cent of the US mango market share, it was assumed that US producers would lose a proportionate share of their market, thereby pegging the loss to US producers at a higher end. To estimate the loss to US mango producers, the quantity exported from India under different scenarios was compared with the total US mango consumption and the proportionate loss of market was assigned to US mango producers. The US market share of Indian mangoes over the years and the supposed equal share loss to US producers is given in Table 10.

For the impact on consumers, due to data unavailability, an alternative method was employed to measure the 'willingness to pay'. Instead of comparing the reserve price and market price of Indian mangoes for US consumers, the price of Indian mangoes was compared with the prevailing market price of a comparable variety. The prevailing market price of domestic US mangoes and the highest of the prevailing price of imported mangoes were taken as the benchmark to compare the price received by Indian mangoes. The underlying assumption was that if US consumers were paying a premium to Indian mangoes over and above the other available varieties, that premium must indicate their gain in satisfaction derived from Indian mangoes. This measure simply captures willingness to pay as an indicator of consumers' gain in value. A detailed theoretical justification for this approach lies in the *Theory of Revealed Preference* (Bernheim and Whinston, 2009).

Since irradiation is the most restrictive regime, the quantity of export remained low and confined to the choicest of mangoes. These mangoes could receive a very high premium in the US. Therefore, the price received by irradiated Indian mangoes was compared

Table 11. Price of mangoes under different conditions: 2004-2006

(US$/tonne)

Year	US domestic	Mexican	Irradiation	Hot water treatment	Free trade
2004	7000	5000	10,000.00	5,707.72	4,554.93
2005	5500	3500	9,748.88	5,776.65	4,604.03
2006	7500	5500	9,647.91	5,991.63	4,714.20

Source: USDA ERS (2008) and author's calculations.

with that of domestically produced US mangoes that fetched the highest price after Indian mangoes. The price of irradiated Indian mangoes was derived by considering the cost escalations over and above the domestic price of Indian mangoes under the irradiation regime. These cost escalations included the costs of transportation, irradiation, other treatments, packaging, export cargo, customs, and a margin for mango importing parties.

Under HWT and free trade regimes, the quantity of export is expected to increase significantly, whereas the quality may not be as high consistently as in the case of mangoes under irradiation regime. Therefore, the price received by Indian mangoes under HWT and free trade regimes was compared with the price of equivalent Mexican mangoes (Gallo, 2009). The Mexican mangoes have market share of about 60 per cent in the US mango market and fetch the highest price among all imported mangoes, barring the Indian premium mangoes. The Mexican mangoes had to compete so far against mangoes from Brazil, Haiti, Peru, and Ecuador (Evans, 2008), which are usually lower in quality but higher in prices due to inefficient supply chains and high transportation cost. With bulk import of Indian mangoes under HWT or free trade regimes, it was expected that a large market share will go to the Indian mangoes due to quality as well as preference of the Indian diasporas. The estimates of prices received by Indian mangoes were arrived at by topping the domestic price of Indian mangoes under the respective regime with the costs of transportation, treatment, packaging, duties, and a margin to importing parties.

The highest price received by the benchmark variety among all the non-Indian mango varieties and the expected price received by Indian mangoes were compared. This difference was multiplied by the quantity traded for an estimate of perceived value gain to the US consumers as a proxy of consumer surplus to US mango consumers. This is in line with the argument that willingness to pay depicts a gain in the utility. The price estimates under irradiation, HWT, and free trade also included the cost of transportation within India, cost of relevant treatment, cost of transportation between India and USA, charges for customs and duties in USA, and margin for US mango importers. All this information was sought through first-hand interaction with the government agencies (APEDA and CISH) and mango exporters (Nawab Pack House, Kakori and KayBee Fresh, Mumbai). The consolidated price estimate thus derived and the comparable benchmark mango prices are shown in Table 11.

The most important estimate for the impact on US is that of potential loss from invasive species and cost of their elimination. Indian mangoes carry twenty pests of concern for US, including fourteen insects, five fungi, and one bacterium (USDA APHIS, 2006). The estimates for cost of control and elimination of pests were directly adopted and adjusted for current prices from Andrew *et al.* (1978). The study considered the loss by pest infestation to the entire citrus industry at the higher end of ten per cent. The loss figure was adjusted with GDP Deflator for the benchmark period and taken to be the cost to the US in the case of free trade. GDP deflator was used as it flexibly captures changed expenditure patterns. Therefore, by reflecting up-to-date expenditure patterns, GDP deflator better accounts for price rise as well as the expansion in the size of the industry.

Since HWT can reduce the potential damage by eighty per cent (OISAT, 2009), the free trade loss figure was reduced by 80 per cent for trade of mangoes under HWT regime. However, since USDA APHIS claims irradiation to be completely effective against all these pests, there is a zero control and elimination cost assumed. The estimates for US thus arrived were

Table 12. Estimates for impact of mango trade on USA

(US$ per annum)

Variables	Trade ban	Irradiation	Hot water treatment	Free trade
Impact on consumers	0	31,038,611	22,674,112	11,546,755
Impact on producers	0	-687,612	-1,287,436	-1,887,260
Cost of control	0	0	-41,772,169	-208,860,847
Total	0	30,350,999	-20,385,494	-199,201,353

Source: Author's calculations.

averaged for annual numbers and are compiled in Table 12. As is evident from the estimate of net welfare gains in Table 12, nuclear irradiation is the only policy regime with positive impact for US. When India was not ready to offer the best choice to the US for eighteen years, US chose the second best policy of trade ban. In the remaining two scenarios, loss from pest infestation erodes completely the comparatively small gain to consumers.

Although free trade of mangoes is the best policy option for India, in no way the US can be convinced to choose free trade of mangoes due to high loss figures for US under that policy regime. The US considers its own payoffs and chooses the policy option of nuclear irradiation of mangoes, which is clearly a dominant strategy and exceeds the payoff to US from any other strategy by a substantial margin.

Sensitivity Analysis

Since the estimates above are conservative in nature, there is a possibility of some margin of error while passing the estimates. Therefore, a sensitivity analysis was performed. The payoffs to India were decisively clear with huge differences of magnitude across scenarios. Further, there is not any theoretical basis to suggest that the value or the direction of these payoffs might substantially differ from the values derived above. However, the impact of mango trade on US was not substantially different under different scenarios. There are three major assumptions (loss from HWT, minor losses despite nuclear irradiation, and no loss to US mango producers), where there is some theoretical basis or evidence to relax these assumptions. Therefore, these assumptions were relaxed one by one and the total effect was consolidated by relaxing all the three assumptions at once (results in Table 13). This sensitivity analysis was done to bring more robustness to the results of this study.

The payoff to USA is within a small range under three of the four scenarios, namely trade ban, irradiation, and HWT. This is seemingly valid as the first strategy was a US policy for 18 years, the second strategy is a US policy for the past 3 years, and the third strategy has been a request by India during all these years; whereas the fourth policy option of free trade exists as a hypothetical possibility. For the sensitivity analysis, the values that may actually be different from the ones assumed for this study include the pest risk estimates under different scenarios and the impact on US producers. These are the two variables for which there exists some theoretical justification or claim, which is different from the assumptions taken for this study so far. Therefore, only these two variables are discussed under varying possibilities for alternative values.

While urging and negotiating with the US to adopt HWT as the applicable standards for import of mangoes, India has maintained that HWT is an effective control measure. Due to emphasis on conservative estimation, the analysis above assumes that the pest losses can be reduced by 80 per cent with HWT. However, there are various studies to suggest that the risk is completely mitigated even with HWT. According to OISAT (2009), HWT is an effective treatment against fruit fly damage, anthracnose, and stem-end rot infestations. According to Waskar (2005), HWT coupled with post-harvest fungicidal treatment reduces disease risk as well as increases shelf-life. According to a study commissioned by National Mango Board of USA, few improvements in the mango HWT process maximize the mango quality, such as hydro-cooling the fruit after HWT and immediate packaging of the fruit without breaking the cold-chain

(Mitcham and Yahia, 2009). However, the study has distinctly noted that HWT is not effective against the mango seed weevil, which is one of the pests of concern to the US. Buganic *et al.* (2005) have suggested that pre-harvest bagging of mango fruits and post-harvest HWT accompanied by fungicidal treatment effectively cures all the diseases of mango and reduce the fruit-fly damage by 80 per cent. Most importantly, Dr Hernani Golez of National Mango Research and Development Center, Guimaras, Philippines, has suggested that HWT can be made more effective by extending the treatment time till the pulp reaches a temperature level of 46 °C, which effectively cures all the problems faced by the mango crops (ABW, 2009).

Since the estimate of potential losses to US stands on the leanest grounds, the same was changed first for the sensitivity analysis. If, as claimed by India, we relax the assumption of loss to USA due to HWT (accompanied with pre-harvest bagging, fumigation, and appropriate cold chain maintenance), the loss of US$ 41 million to the US is nullified, therefore gain to US under HWT regime increases by the same amount. The total payoff to the US from mango trade under HWT regime now stands at a positive figure of US$ 21 million. Since this figure is still lower than the comparable numbers under nuclear irradiation regime, irradiation remains the dominant policy option for the US, *albeit* with a much smaller margin of US$ 9 million only.

As a logical next step to the above, the 'no loss to US' under nuclear irradiation regime was put to test. A study by Iowa State University has distinctly noted that "as in the heat pasteurization of milk, the irradiation process greatly reduces but does not eliminate all bacteria" and that irradiated food helps the product only when all other protocols are followed in the most appropriate manner (Iowa, 2006). If irradiation is not a perfect and leak-proof policy option, it may lead to some losses to the US. Therefore, as the next adjustment, the US was assigned a small loss figure of a tenth of the normal loss figure under the free trade regime. This implies that although irradiation is an effective process, there remains a chance of 10 per cent that the pests of concern may affect the US. This leads to assigning an additional amount of loss to the US to the tune of US$ 20 million. In isolation, this adjustment would not affect the policy choice and irradiation still remains the preferred policy choice of the US with over a US$ 30 million positive margin over HWT regime. However, if this second adjustment is taken into account in continuation to the previous one, the policy choices are seriously affected. With an additional loss of US$ 20 million from irradiation regime and an elimination of the loss of US$ 41 million under the HWT regime make the latter a more attractive policy option for the US.

If the above line of argument is further extended and the study by APHIS is fully accepted, there would not be any loss of market share to the US mango producers (Federal Register, 2006). The study has commented that if the import of mangoes from India is permitted, the effect on US mango producers would be minimal and the benefits of opening up the market to Indian mangoes would outweigh any expected cost to the domestic producers. This would further increase the gain to US under different regimes by the respective figures of loss to the US producers. Since the loss to US producers is so small in magnitude, not crossing a US$ 2 million mark under any circumstances, this is almost insignificant in the decision-making scheme.

Therefore, if we relax some assumptions made earlier and adjust the estimates accordingly, the policy choices for the US may completely change and may not remain as clear as before under the conservative approach. The effect of these adjustments is represented in a summarized tabular form in Table 13. The payoffs

Table 13. Total Payoffs to USA under different scenarios

Trade ban	Nuclear irradiation	Hot water treatment	Free trade
	No loss from HWT[a]		
0	30	21	-199
	Marginal loss from irradiation[b]		
0	9	-20	-199
	No loss to US producers[c]		
0	31	-19	-197
	All adjustments simultaneously[d]		
0	10	22	-197

Sources: (a) ABW (2009) and author's calculations.
(b) IOWA (2006) and author's calculations.
(c) Federal Register (2006) and author's calculations.
(d) Author's calculations.

affected by the respective adjustments are shown in bold.

If all the three adjustments are made simultaneously, or as noted earlier, only the first two adjustments are considered as valid due to the insignificance of the loss amount to the US producers, the policy choices demand a substantial rethink. If the payoffs under all adjustments (Table 13) are considered to be valid, the US has a clear case of deviating from the present policy regime of nuclear irradiation and opting for HWT. Although the difference in magnitude of payoffs is again low, these payoffs represent the lower limit of gains and imply that the difference in payoffs cannot be squeezed any further.

Concluding Remarks

As observed through the detailed estimation process, the policy choices of both the nations are consistent with their respective payoff estimates. However, the policy emphasis and demands are not in synchrony with the best outcomes possible. The demand of India for HWT can be justified only in the case if India may undertake to compensate the US for any losses emanating from a policy change in favour of India. This shall not be much difficult for India; as the regime change increases the benefit to India by over US$ 157 million, whereas the consequential loss borne by the US is about US$ 50 million only. Therefore, India may offer to compensate the US mango producers directly in lieu of a more favourable policy regime. This would keep the US at the same welfare level and at the same time, would increase the gain to India by more than US$ 100 million. Through this exchange, both the nations may reach a Kaldor-Hicks efficient outcome.

The present study is the first of its kind, which has sought to attach an economically justifiable value on the welfare impact on two nations. This study underscores another important point, viz. the impact of risks arising out of invasive species cannot be studied in terms of science alone but it has to be wedded to the economic implications. This is underlined with a clear separation of direct impact on consumers and producers from indirect impact on environment and other indirect stakeholders. By spelling out the pest losses specifically as purely environmental externalities, the separation of direct and indirect impact of SPS standards has been clearly underlined. As shown in the estimation process, the major costs of trade are not the market shares but the costs of pest infestation and control, it is clear that SPS standards is the central issue in these disputes. Therefore, a traditional analysis with enumeration of trade gains or losses would not suffice.

Finally, empirical estimates are subject to data availability limitations and are as strong as the assumptions made. This study has indicated many levels, where more systemic efforts are required for robust data generation, including precise estimation of economic impact of relevant pests of concern for both the countries. Although Indian mangoes do not get substantial premium from top price importers, the demand competition from the US may lead to increased price offers from other countries as well, thereby reducing gains to India from the US trade but enhancing overall gain from mango exports to other countries. From a policy point of view, incorporating transaction costs would be critical for policy decisions and a value-added dimension for future research, as suggested by Abla and Nugent (1996).

Post-Study Update

The estimates in this study are based on the figures supplied by the APEDA (Agricultural and Processed Food Products Export Development Authority), an agency under the Ministry of Agriculture, Government of India. Since the government policy as well as negotiations in this context was guided by the estimates of APEDA, the same were adopted as robust and valid estimates for the purpose of this study.

However, in a very disappointing show of performance, the exports of mangoes from India to the US declined from 202 tonnes in 2008-09 to 175 tonnes in 2009-10 and to 136 tonnes in 2010-11. According to Mr. Vinod Kaul, deputy general manager of APEDA, “The main cause for this decline is the logistics problem, since there is only one irradiation facility (Krushak at Lasalgaon, Nasik), which has the approval of the USDA-APHIS” (Kalbag, 2012). As a consequence of problems with mango exports to USA, export destinations as well as their relative shares remain the same as before.

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Appendix 1

Harberger Triangles give the lowest estimate for consumer surplus as against the other two measures of consumer surplus, namely equivalent variation and compensating variation (Henderson and Quandt, 2003). The Harberger triangle is depicted graphically in Figure 1.

In Figure 1, CD is the initial demand curve for mangoes, with demand q_1 at price p_1. If the price changes due to a policy change, the new price and quantity are p_2 and q_2, respectively. The consumer surplus is given by the triangle CR_1p_1, which is similar to the triangle R_1R_2R. The underlying assumption of linear demand is valid as the actual elasticity of demand in this case is -0.98 for fruits (Mittal, 2006), which is almost linear. We adopted the estimate for all fruits instead of mangoes for two reasons; first, mangoes constitute the largest and highest value share in the Indian fruit basket, and; second, this is the closest estimate available for mangoes. Other studies are too broad, more generic, outdated, or all of these, e.g. Islam (1990).

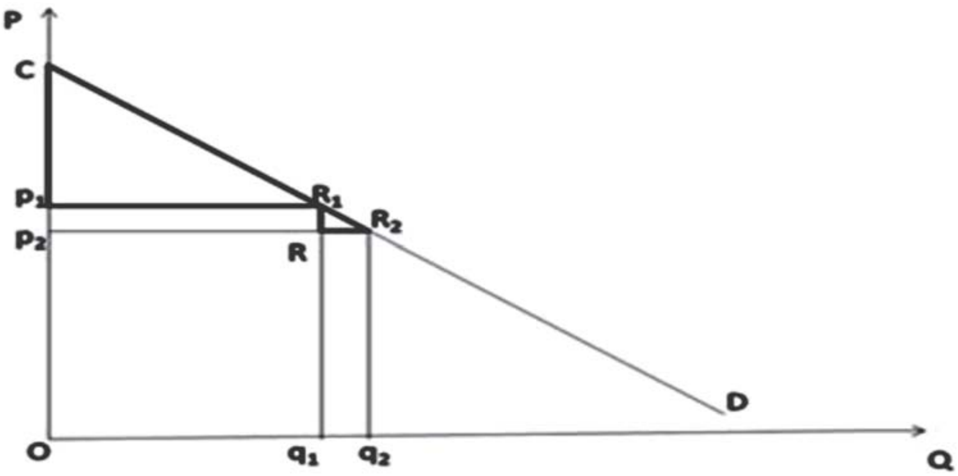

Figure 1: Harberger triangle depicting consumer surplus

$$\text{Elasticity of demand}\,(e_d) = \frac{\Delta Q / Q}{\Delta P / P}$$

$$= \frac{q_1q_2}{p_1p_2} \times \frac{Op_1}{Oq_1}$$

$$= \frac{p_1R_1}{Cp_1} \times \frac{Op_1}{Oq_1}$$ Since [$\Delta CR_1p_1 \approx \Delta R_1R_2R$]

$$= \frac{Op_1}{Cp_1}$$ Since [[$R_1p_1 = Oq_1$]

$$=> Cp_1 = \frac{Op_1}{e_d}$$

= Price / Elasticity of demand