Contingent Valuation in Food Policy Analysis: A Case Study of a Pesticide-Residue Risk Reduction

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Abstract

This study demonstrates how contingent valuation techniques can be used in a cost-benefit analysis of a food safety policy issue. The analysis focuses on banning a specific postharvest pesticide used in fresh grapefruit packinghouses. Benefits of the ban are measured using consumers' aggregated willingness to pay (WTP) for safer grapefruit. A national contingent valuation survey used the payment card method to obtain WTP data. Costs of the ban stem predominantly from increased postharvest losses and were estimated using a model of the market for Florida grapefruit. Results indicate that benefits of the ban outweigh costs.

Key Words: contingent valuation, cost-benefit analysis, food safety, pesticides, willingness to pay

Introduction

While data on market prices allow measurement of benefits and costs associated with policies that change the quantity of food produced, market prices often provide little information about the impacts of policies that affect food quality and/or safety. Nonmarket valuation techniques such as contingent valuation can provide useful information when appropriate price data do not exist. This study demonstrates that point.

Contingent valuation methods encompass personal interviews, mail surveys, and telephone surveys that elicit consumers' willingness to pay (WTP) for nonmarket goods "contingent" on a given hypothetical scenario. For over 30 years, contingent valuation (CV) has been used to measure benefits of a variety of nonmarket goods. Carson *et al.*'s bibliography of CV studies provides a list of over 1,400 studies. Hence, collectively, CV researchers have a solid foundation for designing CV studies.

In the policy arena, pesticide residues in food is a top food safety concern. The Environmental Protection Agency (EPA) is currently involved with mandatory reregistration of all pesticides used in the United States. This comprehensive reregistration uses modern standards and will likely cause the cancellation, suspension, and voluntary withdrawal of some agricultural pesticides. The formal role of economic analysis in this reregistration is limited. Although the EPA does weigh the benefits of using pesticides in food production against any risks, the primary emphasis is on the human toxicity of the chemicals. In particular, section 409 of the Federal Food, Drug, and Cosmetic Act contains the Delaney Clause which prohibits approval of food additives that are found to "induce cancer" (or under the EPA's

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interpretation, to induce malignant or benign tumors) in animals or humans (NRC, p. 2). Hence, chemicals used in processed foods may have high net benefits but still be banned due to some low level cancer risks. For unprocessed food, such as fresh produce, chemicals with low levels of cancer risk can be registered, provided that the benefits from registration outweigh the costs.

This study presents an example of how contingent valuation data can be used in a formal cost-benefit analysis of a potential pesticide ban. Further, this study examined the economic efficiency of banning a postharvest pesticide, sodium ōrtho-phenylphenate (SOPP), from use on Florida grapefruit designated for fresh markets. Specifically, estimates were made of the net benefits and costs of adopting a regulatory policy that bans SOPP from use in grapefruit packinghouses.

While survey techniques (including contingent valuation) have been used previously to measure consumers' WTP for certified pesticide residue-free produce (Weaver *et al.*, Misra *et al.*, Ott, Eom), this study is one of few contingent valuation studies that focuses on a specific pesticide, and it is the first to combine such WTP estimates with estimates of the costs of a pesticide ban to arrive at an overall estimate of the net benefits or costs of a specific pesticide cancellation. Because the pesticide in question is used postharvest, estimation of the costs of the ban must focus not only on the impacts on farmers, but also on packinghouses and shippers. To estimate these costs, information from a survey of Florida grapefruit packinghouses and a model of the Florida fresh grapefruit market were used.

Theoretical Foundation

In theory, the net national benefit (or cost) of a postharvest pesticide ban could be determined by measuring the changes in consumer surplus (CS) and producer surplus (PS) in the relevant markets. The pesticide considered here, SOPP, is a fungicide that reduces postharvest losses from blue molds, green molds, and stem end rots in grapefruit. The fungi that SOPP treats do not cause cosmetic problems, but rather result in the total destruction of affected fruit. Hence, a ban of SOPP would result in higher postharvest losses of grapefruit.

In general, banning a pesticide with limited substitutes can: 1) increase the total quantities of pesticides used, 2) affect cosmetic appearance, 3) limit distance shipped to market, 4) raise costs for users of the banned pesticide, 5) reduce income for producers in certain regions, 6) reduce yields and storability, thereby increasing food costs, and 7) accelerate increased resistance of insects, fungi, and bacteria to the limited pesticides still available for use (Buzby and Skees). These seven impacts are the potential costs of the ban. Beyond potential improvements to worker, environmental, and food safety, two less obvious potential benefits of banning a pesticide with limited substitutes are that regional advantages may be generated by encouraging more production where there are fewer pest problems and that nonusers may benefit from increased produce prices without facing higher costs.

More generally, a pesticide ban could result in higher losses, lower yields, or higher production and processing costs. In any of these cases, the result is a shift of the wholesale supply curve up and to the left. The change in the PS triangle associated with this shift in the wholesale supply curve would include surplus losses or gains to all agents upstream from wholesalers, including shippers, packers, and farmers.

On the consumer side, there are two effects of the pesticide ban. First, the price increase caused by the supply curve shift results in a loss in CS.[1] Second, consumers receive benefits from reduced pesticide exposure (*i.e.*, improvement in food quality), and these benefits would be reflected in the demand curve for the food product shifting up and to the right.

The net impact of both the supply and demand shift on producers and consumers can in principle be measured by comparing PS and CS before and after the ban. Of course, the size of the changes in PS and CS will depend on the shapes of the demand and supply curves, and the size of the shifts in these two curves. The combined shifts make it difficult to unambiguously determine whether PS and/or CS will increase or decrease as a result of the ban.

Pre-ban supply and demand curves can be estimated using standard techniques from available price/quantity data, and the supply curve shift can be projected from information on yields and losses with and without the pesticide in question. Yet, historical price/quantity data typically do not contain information about how the demand curve will shift in response to a change in the risk associated with consuming the commodity. Theoretically, an increase in quality would cause a shift in demand and a subsequent increase in CS and PS. In some situations, market data on demand for pesticide-free organic food could be used to estimate consumer WTP for reduced risk from pesticides. This approach is limited to those few situations where such markets are well developed (*i.e.*, organic food). For most food commodities, however, segregated markets have not developed, and information on the demand shift that would occur in response to an increase in quality is not available. Indeed, for many commodities, consumers are generally unaware of the existing risks from pesticide residues, and it is questionable whether the demand curve would in fact shift in response to a reduction in those risks.

Still, even if consumers are uninformed about current risks, so that preferences over risk changes are unobservable in the market, they gain some benefit from a reduction in those risks. In this study, contingent valuation was used to estimate that benefit. The benefit estimate was then combined with estimates of the net losses of PS and CS due to the expected supply curve shift to arrive at an overall measure of net benefits or costs from the pesticide ban.

Costs from Banning SOPP

In the 1991-92 season, Florida sold 47.8 million cartons of fresh grapefruit with a typical carton containing 35 grapefruit. Grapefruit are chill sensitive meaning that packinghouses cannot rely solely on refrigeration to extend the storage life. Irradiation is not a feasible technology for citrus, because doses high enough to kill pathogens are damaging to the fruit.

In grapefruit packinghouses, the grapefruit is typically prewashed with a chlorine/soap solution to remove field dirt prior to sorting. Methods for applying pesticides depend on the physical and chemical properties of the pesticide. Pesticides can be applied as dips, sprays, drips, foams, and drenches (Love and Buzby). Wax applications are often used as a medium to apply pesticides and to give the grapefruit peel a shiny appearance.

Data from the United States Department of Agriculture's (USDA) 1992 postharvest handlers survey of Florida grapefruit packinghouses and data from a grapefruit model developed by Pana were used to evaluate the CS and PS losses due to a ban on SOPP for Florida grapefruit. The survey found that 40 of the 79 packinghouses used SOPP. The survey also showed that 29 out of 40 SOPP users would switch to another pesticide if SOPP was banned. Of these, 7 identified that they would switch to thiabendazole (TBZ); 10 indicated that they would use what is recommended (*e.g.*, by pesticide suppliers); and 2 indicated that they would use TBZ in combination with another chemical. Although a few packinghouses selected chlorine, imazalil, and assorted detergents, TBZ was the most frequently selected substitute pesticide. Hence, it is assumed that fresh grapefruit packinghouses switch from using SOPP to TBZ.

The largest cost of the policy change would be due to reducing the set of pesticides available to combat resistant strains of fungi. Packinghouses often rotate different pesticides to combat against resistant strains. Since only a few pesticides are registered for postharvest use for grapefruit in the United States, any ban of these pesticides may promote resistant strains. This increase in pathogen resistance would result in increased postharvest losses after a ban on SOPP.

Because SOPP has been continuously available for use in grapefruit packinghouses for decades, the extent to which postharvest losses would increase following an SOPP ban is not known. As a conservative approximation, the estimated change in losses associated with a substitute grapefruit pesticide was doubled to represent the losses from an SOPP ban. In the early 1980's a study in California estimated that adding the postharvest pesticide, Imazalil, to the list of permissible pesticides for use in packinghouses could potentially decrease fresh grapefruit losses from 4% to 8% down to 3% (a reduction of up to

5 percent) (Citrograph). As a worst case scenario, this estimate of a 5% change in losses was doubled to develop the assumption that after the ban, postharvest losses associated with the ban would be equal to 10% of the marketable amount. This would reflect a 20% loss to those grapefruit packinghouses that are currently using SOPP (the USDA's survey found that 51% of Florida's fresh grapefruit is treated with SOPP; Love and Buzby). It is highly unlikely that losses to the grapefruit industry would be greater than 10%.

Based on this worst case scenario for postharvest losses, estimates of several categories of costs to the fresh grapefruit industry (#1 to #3) and to consumers (#4) were constructed:

(1) new fixed costs for packinghouses to switch to TBZ,
(2) higher variable costs for more expensive pesticides,
(3) lost producer surplus due to increased postharvest losses, and
(4) lost consumer surplus due to increased postharvest losses and higher grapefruit prices.

The USDA survey found that there were no fixed costs associated with switching from SOPP to TBZ, because the 40 respondents that used SOPP on their fresh grapefruit during the 1990-91 season also used TBZ during the same season. Therefore the packinghouses already owned the equipment to apply TBZ.

SOPP treatments for grapefruit cost .00012 cents per grapefruit, while TBZ treatments cost .00015 cents per grapefruit.[2] The USDA survey indicated that 86 % of all Florida grapefruit were treated with TBZ which means that 14 % is the upper bound on the amount of fresh grapefruit that could have been treated with SOPP, but not TBZ. When these higher variable costs are applied to the number of fresh Florida grapefruit treated with SOPP and sold in the 1991-92 season, the higher variable costs of treating grapefruit with TBZ (rather than SOPP) amounts to about $7,000 for the entire Florida fresh grapefruit industry. Hence, variable costs are a minor cost of the ban.

An additional cost that might be considered is the increased regulatory and enforcement costs that would result from the ban. Because information was not available to estimate these costs, they are not included in this analysis. Marginal enforcement costs are likely to be small because inspection is required for other nonregistered chemicals.

Loss in Producer Surplus due to Increased Postharvest Losses

We use a model developed by Pana to estimate the producer and consumer surplus losses stemming from the assumed 10% increase in postharvest spoilage. Pana developed a spatial equilibrium model for the Florida grapefruit industry that equilibrates demand and supply components through equilibrium prices in an optimization problem and projects production levels and prices.[3] This model was also used by Spreen *et al.* to study the impacts of banning methyl bromide from use on Florida agriculture, and by Buzby and Spreen to study the impacts of a pesticide ban under a range of loss scenarios. The model maximizes the sum of producer and consumer surplus subject to a demand and supply balance.

Pana's standard spatial equilibrium model was augmented with a cohort population model. The cohort model calculated annual grapefruit production by multiplying the stock of trees for each age group by each age group's average yield per tree and then summing the production in each category. Once total grapefruit production was determined, the spatial equilibrium model allocated the grapefruit among fresh and processed demands in both domestic and foreign markets. The resulting equilibrium prices in turn impact how many new trees are planted. New plantings take several years to begin bearing fruit, and yields increase as the trees mature in age. The model has several assumptions that are important in understanding the results:

(1) All grapefruit supply originates in Florida (Florida actually produces 85 percent of U.S. grapefruit).

(2) Each season, supply is determined by the age distribution of trees, survival rates, and yields by age class.

(3) There are six markets: fresh white domestic, fresh pink domestic, fresh white exports, fresh pink exports, processed exports, and processed domestic.

(4) The model equates Florida's grapefruit supply with the demands in these six markets and obtains market clearing prices for each market and time period.

Conceptually, the cost of postharvest losses to the industry is represented by the loss of profits to the fresh grapefruit industry between the baseline and the 10% loss scenarios. The calculations were performed at the wholesale level, meaning that the fresh grapefruit industry is represented by both grapefruit producers and packinghouses. For the 10% loss scenario, four fresh grapefruit markets were affected: (1) white domestic, (2) pink domestic, (3) white export, and (4) pink export.

Table 1 shows estimated price and quantity data from the grapefruit model for grapefruit marketed at the wholesale level before and after the hypothetical ban.[4] The last column provides the change in total revenue for the grapefruit industry for each of the four markets for fresh grapefruit. This study focused on a one year time horizon because of the uncertainty over: (1) the development of pathogen resistance over time, (2) the import-export market for fresh grapefruit, and (3) and the delayed supply reaction to price due to the perennial nature of grapefruit. Longer term projections would be easier for crops that are annuals and for those crops that have limited imports and exports. A longer time horizon was not used in this study, because it would require information on too many unknowns, such as whether a good SOPP alternative will be developed in the future. PS and CS losses should decrease over time as producers adjust to the increased postharvest losses.

In the calculation of the effect of the ban due to postharvest losses, the change in total revenue was used as a proxy for the change in profits. The change in total revenue was found for each market and summed to get the total change for the fresh grapefruit industry. The total cost of the postharvest losses to the fresh grapefruit industry was over $9 million (table 1). Combined, the variable cost of the ban and the cost of increased postharvest losses represent approximately a 4.5% decrease in total value of production to the fresh Florida grapefruit industry (Fl. Ag. Stat. Serv., p. 16).

Loss in Consumer Surplus Due to Increased Prices

In the United States, the ban would result in increased prices for fresh grapefruit and a loss in consumer surplus. Pink and white grapefruit sold domestically were treated separately because they faced different price changes from the ban.[5] Using prices and quantities from the grapefruit model, consumer surplus for pink and white grapefruit sold were summed to get the total change in consumer surplus. When looking only at the costs of the ban, due to postharvest losses, the estimated total loss in consumer surplus was $18.6 million, with most of the loss (94%) attributable to pink grapefruit.

The estimated total costs of the ban are then $27.7 million. These estimated costs include $7,000 in variable costs, $9 million in postharvest losses and $18.6 million of loss in consumer surplus.

Benefit from Reduced Risk

For fresh grapefruit consumers, the CS loss from the price increase that would result from a ban on SOPP would be offset by a gain due to the reduction in risks associated with exposure to SOPP. The EPA estimates that over a lifetime, the cancer risk from eating SOPP treated grapefruit is 10 in 100,000 persons. In contrast, the cancer risk associated with eating TBZ treated grapefruit is only 10 in 10,000,000 (EPA, Freedom of Information Office). These risks were halved to estimate the risk of death from consuming grapefruit treated with these pesticides.[6]

Consumer WTP for this risk reduction was estimated from data from a two part survey of U.S. fresh grapefruit consumers. A phone survey used random digit dialing to find consumers in all 50 states who had purchased grapefruit for themselves or for their household over the past year and who were willing to participate in a follow up mail

Table 1. Fresh Grapefruit Prices, Quantities, and Total Revenue at the Wholesale Level Under the Baseline and the Ten Percent Loss Scenarios[a]

Grapefruit Type	Baseline Quantity	Baseline Price	10% Loss Quantity	10% Loss Price	Change In Total Revenue
Total	47,884	8.70[b]	43,531	9.37[b]	-9,021,000
Fresh white domestic	2,839	7.27	2,063	7.71	-4,730,000
Fresh white export	13,653	11.27	12,929	11.71	-2,468,000
Fresh pink domestic	22,574	6.76	21,298	7.56	8,408,000
Fresh pink export	8,818	10.16	7,240	10.96	-10,231,000

[a] Quantities are in 1,000 cartons. Prices are in dollars per carton at the wholesale level. The change in total revenue represents the change in dollars between the two scenarios and is rounded to the nearest thousand.
[b] Weighted average price.

survey.[7] The mail questionnaire contained a contingent valuation question that elicited willingness to pay to purchase a safer grapefruit.[8] Pretesting and focus groups for both the phone and the mail surveys helped indicate unclear sections, thus allowing modifications prior to survey implementation.

As a check against potential sample selection bias, 397 consumers who had not purchased grapefruit over the past year also participated in the phone survey to provide demographic and attitudinal data for this group. A tau test showed that "grapefruit consumers" and "current grapefruit nonconsumers" were not significantly different in their beliefs about pesticides.

In the hypothetical market situation posed, the respondent faced a choice between buying one SOPP treated grapefruit at a price of $0.50, or buying one TBZ treated grapefruit at a higher price. Other than the pesticide used, the two grapefruit were identical. To help respondents understand the relative risks, a risk ladder was included in the questionnaire. Loomis and Duvair found the risk ladder to be an effective tool for helping respondents answer contingent valuation questions involving risk changes.

The payment card method was used in the mail survey (Buzby *et al.*). The payment card consisted of one column of 31 value choices ranging from zero to fifty cents above the original purchase price of one SOPP treated grapefruit.[9] Respondents were asked to circle the one amount that indicated the most that they would pay above the purchase price of an SOPP treated grapefruit to buy one TBZ treated grapefruit. Respondents were informed that circling zero meant that they would not pay more for the safer grapefruit. Space for writing in higher WTP values was provided for those willing to pay more than 50 additional cents.

Survey Results

The demographics of the survey sample were comparable to those of the general population with the exception that there were more women and fewer children surveyed.[10] These differences were expected since the samples represent a population of "food shoppers," whereas the census represents the overall population. The phone survey response rate was 65.3 percent. Seventy-eight percent of the phone survey respondents who purchased grapefruit were willing to participate in the follow up mail survey. There were 548 returned payment card surveys giving a return rate of 78.3%.[11] Of the 548 returned surveys, 512 had completed WTP questions (93.4%). Of the 512 WTP responses, 28 were greater than 50 cents (5.5%).

WTP for the risk reduction is defined as the maximum additional amount that a consumer would be willing to pay to purchase one TBZ-treated grapefruit, instead of a SOPP-treated grapefruit. Undeliverable surveys were dropped from the sample. Following the suggestion of Mitchell and Carson (1989), we make the conservative assumption that nonrespondents value the good at $0. All unit non-responses (unreturned surveys) and item non-responses (returned surveys with the CV question unanswered) were therefore assumed to have a zero WTP.[12] Without that adjustment, the mean WTP was $0.28, with a median of $0.20. With the adjustment, the mean WTP was $0.19, with a median of $0.10.[13]

Regression Analysis of Consumers' WTP

To better understand factors influencing consumer demand for improved food safety, WTP for the safer grapefruit was regressed on demographic and attitudinal variables, using all returned and completed surveys. The demographic variables were gender, age, race, education, household income, and household size. The GENDER variable was equal to "0" for females and "1" for males. AGE was the difference between 1993 (year survey was implemented) and the respondent's birth year. RACE was equal to "0" for whites and "1" for nonwhites. EDUCATION was the number of completed school years. INCOME was a discrete variable (1 to 7).[14] HOUSEHOLD was the number of people the respondent normally purchased groceries for (including herself/himself). Two attitudinal factors represent consumers' attitudes towards food safety. ATTITUDE 1 was equal to "1" if the respondent strongly agreed with the statement that "the current levels of pesticides in fresh fruits and vegetables are safe" and was equal to "5" if the respondent strongly disagreed with this statement.[15] ATTITUDE 2 was equal to "1" if the respondent strongly agreed with the statement that "the government should ban all pesticides" and was equal to "5" if the respondent strongly disagreed with this statement.[16] The expected sign on the coefficient for ATTITUDE 1 is positive and negative for ATTITUDE 2. Table 2 lists the regression results and indicates the significant variables.

In the regression, the dependent variable is the log of consumers' stated WTP values for one grapefruit treated with the relatively safer pesticide.[17] The OLS regression had an R^2 of 10 % with several statistically significant variables. Cross sectional data, like that used here, typically result in a low R^2 (Kmenta, p. 234). Two variables were significant at the 1 % level (AGE, ATTITUDE 2) and two variables were significant at the 5 % level (INCOME, ATTITUDE 1).

The regression results show that WTP for the safer grapefruit was inversely related to income. This result would seem to be opposite to expectations, if food safety is a normal good. Indeed, some previous studies (Elnagheeb and Jordon, van Ravenswaay and Hoehn 1991a) have found that WTP increases with higher levels of income, contrary to the result obtained here. Others (Byrne *et al.*, Dunlap and Beus, Jussaume and Judson) have found that concern over food safety decreases as income increases, consistent with the current study. van Ravenswaay argues that respondents with higher income may be less concerned about food safety because they have access to better information about pesticide risks.

van Ravenswaay also argues that respondents with higher education levels should be better able to process that information, and therefore less concerned about pesticides. Evidence on the affect of education on concern over pesticide risks is mixed, with some studies finding a positive relationship, some a negative relationship, and others, including the current study, finding little or no association between education and concern (van Ravenswaay).

The regression also shows that WTP for the safer grapefruit is lower for older respondents. Many of the older respondents commented that they were on a fixed budget and couldn't pay more even if they wanted to. Also, many older respondents commented that at their age, food safety risks would

Table 2. OLS Regression Results Using Logged WTP as the Dependent Variable[a]

Variable	Coefficient Estimate	T-Statistic
INTERCEPT	4.32	3.78
SEX	-.08	-.25
INCOME	-.17	-2.13**
AGE	-.02	-2.48*
ATTITUDE 1	.24	1.79**
ATTITUDE 2	-.39	-2.97*
EDUCATION	-.01	-.10
HOUSEHOLD	.07	.79
RACE	.06	.12

[a] Numbers in parentheses are t-statistics. The superscripts * and ** correspond to levels of statistical significance of 1 percent and 5 percent, respectively. N=370 respondents. McFadden's R^2 was 10%.

not affect their life expectancy. Perhaps, those who are older are less worried about cancer risks from pesticides because of the long lag times between exposure and disease.

The current study found that attitude about pesticide residue was an important indicator of consumers' WTP for food safety. Both attitudinal variables had the expected signs; WTP increased with consumers' concern over pesticide risk and the strength of the belief that the government should ban all pesticides.

In general, comparison of WTP values between studies is difficult because of the variability between surveys in terms of units of measurement, demographic categories of consumers, and areas surveyed. The most comparable study is that of van Ravenswaay and Hoehn (1991b). They found that consumers were willing to pay around 17 % in excess of the purchase price (per pound), annually, to avoid Alar in fresh apples. In the current study, respondents were willing to pay, on average, 38 % more per grapefruit to avoid SOPP. However, this comparison is limited due to the differences in the scenarios.

Benefits

For the benefit aggregation, data from Pana's model provided the post ban quantity of individual fresh grapefruit for the 10% loss scenarios. The post ban quantity of grapefruit was multiplied by 51% to get the number of fresh Florida grapefruit treated with SOPP.[18] This average number of fresh grapefruit treated with SOPP was multiplied by the average WTP to obtain the aggregated benefits of the SOPP ban. Using the estimate of WTP, the benefit estimate is over $80 million per year.

Implied Value of Life

As a check on the validity of our CV estimate of the benefits of the risk reduction, we calculated the value of a statistical life (VOL) that our estimate implied. Viscusi (1994) suggests that the best VOL estimate lies between $3 and $7 million per life. Fisher *et al.*'s survey of the wage-risk-premium literature on the willingness to pay to prevent death concluded that reasonably consistent values of a statistical life range from $1.6 to $8.5 million dollars (1986 dollars) (Fisher *et al.* 1989). These values are based on a generic value of life for the working population. Updated to 1993 dollars using the change in average gross weekly earnings (GPO), Fisher *et al.*'s range becomes $1.96 to $10.4 million dollars for each statistical life lost. The average of the midpoints of Visucsi's and Fisher *et al.*'s ranges in 1993 dollars is $5.8 million.

A value of life estimate derived from our CV survey was calculated by determining: (1) the average number of grapefruit consumed per year by a grapefruit consumer, (2) the annual WTP expenditure to buy the safer grapefruit, and (3) the total WTP per person to reduce their risk of dying from consuming fresh grapefruit by 99.99%. The annual WTP to buy the safer grapefruit ($2.71) was found by multiplying the average number of grapefruit consumed per year by grapefruit consumers (13.8) by the WTP per grapefruit (19.6 cents). The total WTP per person for the risk reduction ($204.22) was found by multiplying the annual WTP expenditure to buy the safer grapefruit ($2.71) by 75.3 years, which is the average lifespan in the U.S. (U.S. Bureau of the Census). The value of a statistical life was found by dividing the total WTP per person for the risk reduction ($204.22) by the difference in lifetime risk (4.995 per 100,000 grapefruit consumers). The resulting VOL estimate was $4.1 million, which falls close to the middle estimate of both Viscusi's and Fisher *et al.*'s ranges.

Conclusion

The estimated benefits ($80 million) of banning SOPP far exceed the estimated costs ($27.7 million)(table 3). This is true even though the assumptions regarding the projected increase in postharvest loss and the supply response portray a worst case scenario. While the actual increase in postharvest loss is difficult to project, it is likely to be less than the 10% assumed here. Lower postharvest losses would reduce the costs of a ban, without impacting the benefits. This application of cost-benefit analysis revealed the importance of postharvest losses, an area that should be considered by policymakers when making decisions on pesticide regulation.

The analysis was restricted to the short run, with no supply response. Over a longer time period, grapefruit suppliers would adjust to the increased postharvest loss, mitigating the costs to the industry. The results of the grapefruit model suggest the grapefruit industry in Florida may currently be overplanted, and that there will be an oversupply of grapefruit in the future. If this is true, the long run costs to the industry of an increased postharvest loss will be even lower, because the loss would help absorb some of the oversupply.

Use of contingent valuation data rather than market prices does raise concern over the validity of CV responses. Mitchell and Carson discuss several studies that demonstrated that CV can generate benefit estimates comparable to estimates from market-based approaches. Further, the CV methodology has highest validity when the hypothetical scenario is similar to a familiar market choice situation (Cummings *et al.*), as it is in our survey. Finally, throughout the statistical analysis, the most conservative approach, *i.e.* the approach that would generate the smallest benefit estimate, was followed, with the intention that our benefit estimates would serve as lower bounds.

Still, there are reasons for caution in interpreting the WTP estimates presented here. First and foremost, the WTP for a risk reduction based on a purchase decision regarding a single grapefruit was estimated. Had WTP been elicited in terms of a year's supply of safer grapefruit, aggregate benefits would likely have been lower. This was not done due to the difficulty in posing a realistic hypothetical purchase scenario. Second, the benefit estimates presented are valid only in the policy context of a single decision regarding this particular pesticide. If a ban of SOPP is considered as part of a package of policies regarding food safety, it is not appropriate to value each part of the package and sum those values to arrive at the total value of the package. Such an "independent valuation and summation" approach would overstate the total benefits of the package (Hoehn and Randall). This latter concern is not unique to CV estimates of benefits, however, but applies equally to market-based benefit estimates.

This study revealed the importance of SOPP to fresh grapefruit packinghouses. Although grapefruit packinghouses could switch to an alternative pesticide with only minimal variable costs increases, postharvest losses would increase. Florida packinghouse representatives made it quite clear that if SOPP was banned, their biggest concern would be an increase in postharvest losses due to pathogen resistance.

If postharvest losses of grapefruit increase significantly after an SOPP ban, grapefruit exports will be affected because the U.S. exports one-third of its annual grapefruit production designated for fresh markets. More distant grapefruit importing countries will be particularly affected because of the increased difficulty of maintaining quality during

Table 3. Estimated Net Benefits of the SOPP Ban (in dollars)

Category of Impact	Benefit or Cost
Grapefruit Industry:	
Increased fixed costs	0
Increased variable costs	-7,039
PS loss	-9,021,465
Consumers:	
CS loss due to price effect	-18,627,447
Benefit from reduced risk	80,063,710
Net impact:	52,407,759

transit. For example, half of all U.S. fresh grapefruit exports are sold to Japan. The 45-day ocean shipping time to Japan may push the limits on maintaining quality grapefruit during export. Those grapefruit packinghouses that focus primarily on export sales will likely be more affected than those that focus on domestic sales.

In short, the results of the cost-benefit analysis show that if SOPP is banned, growers would be negatively affected, even though wholesale prices for both pink and white U.S. grapefruit would increase in both the domestic and export markets. Estimated quantities sold of fresh pink and white grapefruit in both domestic and export markets would decrease. Grapefruit consumers would likely pay higher prices for fresh grapefruit but would benefit from a reduction in risk. Overall, the estimated benefits to consumers of increased safety far outweigh the increased prices and the estimated costs to the industry.

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Endnotes

1. This loss in CS would also include retailers.

2. Tom Tsun of FMC Corporation provided variable cost estimates for treating grapefruit with SOPP and TBZ. FMC is a main supplier of equipment, pesticides, and services to Florida's grapefruit industry.

3. Tom Spreen (Univ. of Florida) modified the model for this analysis.

4. Total amounts sold of both white and pink grapefruit decrease by 10% of the with-ban quantities, or by 9.1% of the without-ban quantities.

5. The results of the model showed that the price of one carton (containing 35 grapefruit) of pink grapefruit increased by 80 cents while the price of one carton of white grapefruit increased by 44 cents, These price changes were multiplied by the average quantity of grapefruit for the two scenarios (by type) to get the change in consumer surplus.

6. According to Ralph Christenson of the Radiation Sciences Department at the University of Kentucky, rough estimates of risk of death can be obtained by halving the risk estimates of cancer.

7. The survey found that 43.3 percent of U.S. primary food shoppers had purchased fresh grapefruit for their households in the past year.

8. The phone survey used Dillman's Total Design Method while the CV mail survey followed techniques outlined by Dillman and by Mitchell and Carson. Copies of these surveys are available from the authors.

9. In the three focus groups, averaging ten people per group, there was heated debate about the upper column limit and the choice between one or two penny increments. Although the first choice would have been to use penny increments throughout the payment card, in the end, penny increments were only used between zero and ten cents because of space limitations.

10. The census shows that 51.2% of the 1991 U.S. population were female whereas 75.7% of phone survey respondents and 78.4% of mail survey respondents (all versions) were female. The census shows that 21.67% were under 15 years old whereas there were no mail survey respondents in this age bracket.

11. If undeliverable addresses were excluded, the response rate for the mail survey was 82.2 percent.

12. One PC WTP value equal to $10.00 was deemed an outlier and discarded.

13. The dichotomous choice (DC) method was also used in the survey (Buzby, Ready, and Hu). For this paper, we present the PC method because it generated a more conservative estimate. Both the DC and PC methods provide positive net benefits. The DC sample size was roughly equivalent to the PC sample size, yet the mean WTP for the DC surveys was 69.4 cents for one TBZ-treated grapefruit (median was 21.5 cents).

14. For the INCOME variable: "1" represents those participants whose total 1991 before-tax household income was less than $10,000; "2" represents income between $10,000 and $14,999; "3" represents income between $15,000 and $24,999; "4" represents income between $25,000 and $34,999; "5" represents income between $35,000 and $49,999; "6" represents income between $50,000 and $74,999; and "7" represents incomes greater than $75,000.

15. ATTITUDE 1 was equal to: "2" if the respondent agreed, "3" if the response was neutral, and "4" if the respondent disagreed.

16. ATTITUDE 2 was equal to: "2" if the respondent agreed, "3" if the response was neutral, and "4" if the respondent disagreed.

17. To allow log transformation, zero WTP responses were recorded as $0.005. Use of different small values did not substantively affect regression results.

18. The post-ban quantity was used because of our conservative assumption that there was no demand shift from a change in grapefruit quality.