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Willingness to Pay for Pesticides' Environmental Features and Social Desirability Bias: The Case of Apple and Pear Growers

R. Karina Gallardo and Qianqian Wang

We conducted a discrete-choice experiment using direct and indirect valuation to determine the value apple and pear growers place on environmental features when choosing pesticides to control for first-generation codling moth. Apple growers' willingness-to-pay (WTP) to decrease the probability of pesticide toxicity to natural enemies was $26.03/acre under direct valuation and $26.60/acre under indirect valuation. Pear growers' WTP was $40.06/acre under direct valuation and $33.37/acre under indirect valuation. We found no evidence of social desirability bias, since differences across WTP obtained through either valuation were not statistically significant. Our results underscore the importance of understanding context when investigating social desirability bias.

Key words: biological control, discrete choice experiments, social desirability bias

Introduction

Agricultural fruit producers are committed to the production of high-quality fruit with respect to wholesomeness, appearance, sensory characteristics, and environmental and social sustainability. To produce fruit of this quality, growers must select a bundle of mechanisms that protect crops from pest damage. Pest management systems typically rely on pesticide use, but environmentally sustainable pest management systems, such as biological control, are gaining popularity. These systems use pests' natural enemies to control pest levels (Brunner, 1993) and are divided into three types: classical, conservation, and augmentation.[1] Conservation is considered the most efficient, as it prevents the disruption of natural enemies already present in an orchard and therefore precludes the need to apply additional pesticides to control for secondary pests (Jones et al., 2009).

Given the benefits of biological control and the proliferation of pesticides with unknown effects on natural enemies, one wonders if growers see any value in conserving natural enemies in their orchards and whether this is reflected in their choice of pesticides. One way to elicit growers' values on this topic is through choice experiments, but these experiments have been questioned, as their hypothetical nature may misrepresent real choice behavior. One source of bias is the social

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[1] Classical biological control introduces natural enemies from a pest's native range into an area where native natural enemies do not provide control. Conservation biological control encourages practices that will not disrupt natural enemies already present. Augmentation biological control is the artificial release of natural enemies to reestablish a balance that has not been maintained naturally (Brunner, 1993; Jones et al., 2009).

desirability bias that happens when respondents' desire to adhere to societal norms inhibits them from expressing their true views (Leggett et al., 2003).

The objectives of this study are threefold. The first objective is to measure the value growers place on pesticides that conserve natural enemies in an orchard. For this, we conducted a discrete-choice experiment to calculate apple and pear growers' willingness to pay (WTP) for features of pesticides related to the environment, including nondisruption of natural enemies. The second objective is to assess evidence for social desirability bias. Here, we compared WTP estimates obtained through direct and indirect questioning (hereafter direct and indirect valuation). If WTP for pesticides' features with positive social connotations and measured through indirect valuation is significantly higher than WTP obtained through direct valuation, it would indicate the presence of social desirability bias. The third objective is to estimate the prediction accuracy of estimates obtained through direct and indirect valuation. We applied the prediction index indicating the number of times the model predicted actual pesticide choices. We also tested which approach more accurately predicts actual pesticide market shares by using the mean square error and out-of-sample log likelihood function.

Several studies have investigated social desirability bias. Johannson-Stenman and Martinsson (2006) proposed a model in which utility, besides being a function of the good's characteristics, was a function of the individual's perceived concern relative to the average perceived concern of others. Both Lusk and Norwood (2009a,b) and Norwood and Lusk (2011) found that indirect valuation had the potential to provide better predictions of field behavior if social concerns were the primary contributor to bias, and could therefore provide potentially improved predictions of WTP and market shares. The authors proposed a model in which an individual's utility was composed of two additively separable components: ethics and wealth/consumption. The point at which the individual was indifferent between two different levels of the good's attribute was the tradeoff between the marginal utility of having an "upgraded" attribute and the marginal utility of income. The latter was adjusted by a factor representing the marginal utility of a normative response. Olynk, Tonsor, and Wolf (2010) conducted an empirical application of the indirect valuation format to measure WTP for milk and pork chop production process attributes. They found that indirect valuation yielded a more accurate representation of consumer values compared to direct valuation. Our study is unlike other studies in that we investigated profit-maximizing producer choices. When choosing a pesticide, growers factor in the ethical and moral issues related to worker health and the environment as well as the need to protect their crops from pests. To the best of our knowledge, no study has investigated the social desirability bias phenomenon where the decision makers are profit-maximizing agents rather than utility-maximizing agents.

Scant research has elicited growers' preferences for pesticide features that could affect the environment. Lohr, Park, and Higley (1999) estimated that growers in the Midwest (Illinois, Iowa, Nebraska, and Ohio) were willing to pay $8.25 per acre to avoid moderate risks to the environment from pesticide applications. Cuyno (2001) found that onion growers in the Philippines were willing to pay $17.00, $14.50, $14.43, $15.53, and $13.78 per crop season to reduce pesticide risks to human health, beneficial insects, birds, animals, and aquatic organisms, respectively. Hasing et al. (2010) determined that U.S. soybean farmers were willing to pay $27 to $38 per acre more to avoid the words "Warning" or "Danger" on a herbicide label and $15 per acre more to avoid using herbicides with groundwater statements. All of these papers investigated annual row crop growers' values for pesticides features related to the environment. Our study is the first of its kind to investigate fruit growers' preferences for pesticide features affecting biological control systems. Unlike annual row crops, fruit crops exhibit higher financial, production, and marketing risks as well as longer juvenility periods that delay full production (Gallardo, Taylor, and Hinman, 2010; Galinato and Gallardo, 2011). We explored whether increased risks associated with fruit production impact the value that fruit growers place on pesticides' environmental related features.

Background

This study examines apples and pears, two popular fruit crops grown in the U.S. Pacific Northwest. Production practices for both crops are somewhat similar. Major variable cost centers include soil preparation, planting trees, pruning, training, chemical and fertilizer application, pollination, irrigation and energy, harvest labor, and packing costs. The total annual cost of producing apples, based on a series of production assumptions, is $11,923 per acre (Gala variety) and pears $9,684 per acre (Anjou variety) (Gallardo, Taylor, and Hinman, 2010; Galinato and Gallardo, 2011). One pivotal difference between these crops is that dwarf rootstocks are available for apples but not for pears. These dwarf rootstocks have led to various horticultural improvements, including reduced tree size, increased planting density, and increased tree precocity (Robinson, Lakso, and Carpenter, 1991; Hampson, Quamme, and Brownlee, 2002). Additionally, the less abundant tree canopy associated with these rootstocks allows for more targeted pest control and reduces the need for multiple sprays. These improvements have not been realized for pears grown in most regions of the United States (Jacob, 1998), particularly the Pacific Northwest. No dwarf rootstock is currently adapted to the region's climate conditions. As such, horticultural management is more costly and challenging for pear growers. In addition, the mix of pests affecting these crops is different. The most damaging pest for apples is the codling moth (*Cydia pomonella*), whereas for pears it is the pear psylla (*Cacopsylla pyricola*) as well as the codling moth.[2]

The most popular pesticide for controlling codling moth in both apples and pears is the organophosphate (OP) azinphosmethyl (AZM or Guthion), but it poses potential health risks to orchard workers and negative impacts to the environment. The Food Quality Protection Act passed by Congress in 1996 mandated reductions in OP pesticide use, including the complete phaseout of AZM by September 2013 (U.S. Environmental Protection Agency). There are alternatives for controlling codling moth that are less toxic than OP pesticides, but these require more precise application and integration with other pest management systems such as biological control. These OP alternatives are perceived as less effective and more expensive than AZM. Given that these new systems are more complex and knowledge intensive, transitioning from AZM to OP alternatives has been a challenge for the apple and pear industries (Goldberger, Lehrer, and Brunner, 2011).

Data

Data were obtained from in-person interviews at group meetings with Washington apple growers in November and December 2010 and with Oregon pear growers in March 2011.[3] The apple growers' sample consisted of thirty-five individuals representing 26,864 acres, 16% of apple-bearing acreage in Washington. Table 1 presents summary statistics describing the characteristics of these operations. The pear growers' sample included twenty-six individuals representing 4,735 acres, 29% of pear-bearing acres in Oregon. Table 2 presents summary statistics describing these operations.

[2] J. F. Brunner, professor in the Department of Entomology and director of the Tree Fruit Research and Extension Center, Washington State University. Personal communication, November 21, 2011.

[3] The apple growers who participated in the interviews were part of the Pest Management Transition Project (PMPT) implementation units, which the Washington State Legislature funded for two years in order to enhance understanding of new pest management technologies through educational programs and communication of research-based knowledge. Fourteen implementation units were distributed geographically across the principal apple production regions of Washington State (Washington State University. Tree Fruit Research and Extension Center, 2008). For this study we visited seven implementation units and were able to interview thirty-five individuals. Of this group, eleven individuals were apple operation owners, four were hired managers, fourteen were pesticide consultants affiliated with an apple operation, three were owners and hired managers, and three were owners and pesticide consultants affiliated with an apple operation. All persons interviewed had the decision-making power to select the pesticide program to be used in the orchard. For simplicity we call this group "apple growers." The Oregon State University Mid-Columbia Agricultural Research and Extension Center (OSU-MCAREC) facilitated meetings with pear growers. Of the twenty-six individuals interviewed, twenty-three were pear operation owners and three were owners and pesticide consultants affiliated with a pear operation. All twenty-six interviewees came from pear-producing areas in Hood River, OR.

Table 1. Summary Statistics Apple Grower Responses

Definition	Value
Average (median) number of acres	
Owned	196.94
	(56.00)
Rented	52.00
	(45.00)
Managed/consulted but did not own/rent	1112.38
	(1000.00)
Location (=1 if respondent has orchards in any county listed below)	
Adams	0.11
Benton	0.08
Chelan	0.17
Douglas	0.19
Franklin	0.03
Grant	0.42
Okanogan	0.17
Yakima	0.39
2010 Annual Gross Income (=1 if respondent falls in any category listed below)	
\$75,000–\$99,999	0.14
\$100,000–\$249,999	0.17
\$250,000–\$499,999	0.14
\$500,000–\$1 million	0.11
> \$1 million	0.44
Average number of years involved in apple production	19.08
Pesticide for first-generation codling moth in 2010 (=1 if respondent used any pesticide listed below)	
Altacor	0.43
Assail	0.11
Cydxcm	0.06
Delegate	0.14
Guthion	0.14
Intrepid	0.06
Rimon	0.06

Notes: Numbers in parentheses indicate the median of the distribution.

Before presenting the questionnaire, researchers explained to growers the purpose of the questionnaire, the methodology, and the assumptions made for each scenario. The questionnaire consisted of three sections. The first section included questions about orchard operation characteristics. The second section asked about pesticides used to control codling moth during the 2010 season, assuming first-generation application and a moderate initial pest pressure. This section also asked about perceptions of the pesticide used with respect to effectiveness, toxicity to natural enemies, wildlife, aquatic organisms, and reentry intervals. The third section presented sixteen choice experiment scenarios. The first eight scenarios used a direct valuation format to ask respondents what they themselves would choose in certain scenarios. The subsequent eight scenarios used an indirect valuation format and included the same questions, but asked respondents what they believed the average grower would choose. An example of the scenarios is presented in figure 1.

Table 2. Summary Statistics Pear Grower Responses

Definition	Value
Average (median) of the number of acres	
Owned	149.04
	(110.00)
Rented	56.60
	(21.00)
Managed/consulted but did not own/rent	98.00
(140.00)	
Location (=1 if respondent has orchards in any county listed below)	
Yakima	0.12
Hood River	0.88
2010 Annual Gross Income (=1 if respondent falls in any category listed below)	
< $10,000	0.04
$25,000– $49,999	0.04
$50,000– $74,999	0.08
$100,000– $249,999	0.11
$250,000– $499,999	0.15
$500,000– $1 million	0.27
> $1 million	0.31
Average number of years involved in pear production	24.57
Pesticide for first-generation codling moth in 2010 (=1 if respondent used any pesticide listed below)	
Altacor	0.38
Assail	0.08
Calypso	0.04
Cydxcm	0.04
Delegate	0.35
Guthion	0.04
Pheromone	0.08

Notes: Numbers in parentheses indicate the median of the distribution.

Each respondent was randomly assigned to one of two blocks of sixteen scenarios in the third section. Each block presented the same scenarios, and each scenario presented respondents with three choices of pesticide (options A, B, and C) and assumed an existent moderate pest pressure. Options A and B presented a combination of different probabilities of pesticide effectiveness in controlling first-generation codling moth.[4] Options also included different probabilities of pesticide toxicity to natural enemies, wildlife, and aquatic organisms; pesticide reentry levels; and prices. Respondents were presented with definitions for each pesticide feature. For example, a high probability of effectiveness was defined as 99% of all codling moths killed. Moderate and low probabilities of effectiveness are associated with 90% to 95% and 80% to 90% of codling moths killed. A pesticide toxic to natural enemies, wildlife, or aquatic organisms was defined as a product that would decrease the presence of natural enemies or negatively impact wildlife or aquatic organisms. Reentry interval was defined as the period of time individuals must wait to enter the

[4] Pesticides are applied several times throughout the production season, and in each season the mix of pesticide applications is different. The first-generation codling moth application refers to the appearance of codling moth pupae when the first apple and pear blossoms begin showing a pink color (J. F. Brunner, personal communication, November 21, 2011).

Question C-1
PLEASE PUT AN "X" IN THE BOX BELOW THE INSECTICIDE OPTION YOU WOULD USE. SELECT ONLY ONE INSECTICIDE.

	Insecticide A	Insecticide B	Insecticide C
CODLING MOTH CONTROL	50% chance of resulting in HIGH control & 50% chance of resulting in LOW control	90% chance of resulting in MODERATE control & 10% chance of resulting in LOW control	The insecticide I used last season to control for codling moth
NATURAL ENEMIES	0% chance of resulting TOXIC	50% chance of resulting TOXIC	
WILDLIFE	10% chance of resulting TOXIC	10% chance of resulting TOXIC	
FISH	10% chance of resulting TOXIC	50% chance of resulting TOXIC	
REENTRY INTERVAL	14 DAYS	14 DAYS	
PRICE ($/unit)	$30	$30	
	I would use	I would use	I would use

Figure 1. Example of a Choice Experiment Scenario

orchard after a pesticide application and was associated with the risk of a negative effect of pesticide residuals on workers' health. Option C in each scenario was the pesticide used by the respondent during the 2010 season to control first-generation codling moth and was the same pesticide covered in section two of the questionnaire. That is, we provided each respondent with the option to choose pesticide feature levels corresponding to their own recent experiences.

We used a factorial design to create random combinations of probabilities of effectiveness and levels of toxicity, reentry intervals, and prices. Reentry intervals and prices were within the bounds of actual values for pesticides used in apples and pears to control for codling moth. The pesticide feature levels used to create the random combinations of probabilities are reported in table 3. Since a full factorial design would have yielded 50,000 scenarios ($5^5 \times 4 \times 4$), we used a main effects fractional factorial design.[5] The SAS procedures PLAN and OPTEX were used to create a design with random sixteen choice scenarios that maximized D-efficiency (94.3). Considering that individuals would have to respond to a total of thirty-two scenarios (sixteen direct and sixteen indirect questions) leading to potential fatigue, we randomly divided the thirty-two scenarios into two blocks of sixteen scenarios each (eight direct and eight indirect questions). This created two versions of the questionnaire; each respondent was assigned a version randomly.

[5] We base our choice of design on findings by Lusk and Norwood (2005) that indicate that large experimental designs with perfect orthogonality do not necessarily perform better than designs that minimize the efficiency criterion. However, fractional factorial designs appropriate for linear-in-the-parameter models might not be adequate for nonlinear models used to analyze discrete choice experiment outcomes (conditional logit and heteroskedastic extreme-value logit). Nonetheless, Ferrini and Scarpa (2007) used Bayesian algorithms to create D-efficient designs. They found that if quality *a priori* information is lacking and there is strong uncertainty about the real data-generating process that is common to environmental valuation, practitioners might be better off with shifted designs built from conventional fractional factorial designs for linear models.

Table 3. Pesticide Features, Probabilities, and Mean Levels in the Questionnaire

Pesticide Features	Levels				
Probability of high effectiveness in controlling codling moth	0	10	50	90	100
Probability of moderate effectiveness in controlling codling moth	0	10	50	90	100
Probability of toxicity for natural enemies (%)	0	10	50	90	100
Probability of toxicity for wildlife (%)	0	10	50	90	100
Probability of toxicity for aquatic organisms (%)	0	10	50	90	100
Reentry interval (days)	0.17	0.5	3	14	
Price[a] ($/acre)	20	30	40	60	

Notes: [a] Price does not include application costs, only chemical costs per acre.

Methods

Questionnaire data were analyzed using a random utility model, which was chosen because we modeled choices in which growers consider environmental amenities when purchasing a pesticide. The random utility model is represented by:

$$U_{ij} = V_{ij} + \varepsilon_{ij}, \tag{1}$$

where U_{ij} is the utility derived by grower i when choosing pesticide j; V_{ij} is the nonstochastic component of the utility, typically assumed to be certain; and ε_{ij} is the error component that captures the factors unobserved to the researcher.

Pesticide effectiveness and toxicity are uncertain because they depend heavily on stochastic events such as temperature, rainfall, relative humidity, pest recurrence, and natural enemies' ecology and behavior, among others. Hence, we follow Roberts, Boyer, and Lusk (2008), who claimed that the probability of occurrence of an attribute could be included as another attribute of choice; this is consistent with random utility theory.

The systematic portion of the utility is then given by:

$$\begin{aligned} V_{ij} = {} & \alpha_j + \beta_1(Phigh)_{ij} + \beta_2(Pmoderate)_{ij} + \beta_3(Ptoxic\ natural\ enemies)_{ij} + \\ & \beta_4(Ptoxic\ wildlife)_{ij} + \beta_5(Ptoxic\ aquatic)_{ij} + \beta_6(reentry)_{ij} + \beta_7(price)_{ij}, \end{aligned} \tag{2}$$

where α_C is the alternative specific constant that represents the utility of choosing the status quo pesticide (j =option C), *Phigh* is the probability that pesticide j controls codling moth with high effectiveness; *Pmoderate* is the probability of moderate effectiveness; *Ptoxic natural enemies* is the probability of toxicity for natural enemies; *Ptoxic wildlife* and *Ptoxic aquatic* are the probability of toxicity for wildlife and aquatic organisms; *reentry* is the period that the worker has to wait to reenter the orchard once the pesticide has been applied; and *price* is the price of pesticide per acre (considering only the prices for the chemicals, not application costs). We had three levels of efficiency—high, moderate, and low—and each was associated with a probability level (0%, 10%, 50%, 90%, and 100%). We compared the probability of each efficiency level (high and moderate) against the probability of a low efficiency; thus the probability for efficiency in all scenarios would always sum to 100%.

To control for the effect of respondents' acreage, we interacted a weight factor for acres with each choice attribute and price, following:[6]

$$\begin{aligned} V_{ij} = {} & \alpha_j + \beta_1(Phigh \times acres)_{ij} + \beta_2(Pmoderate \times acres)_{ij} + \\ & \beta_3(Ptoxic\ natural\ enemies \times acres)_{ij} + \beta_4(Ptoxic\ wildlife \times acres)_{ij} + \\ & \beta_5(Ptoxic\ aquatic \times acres)_{ij} + \beta_6(reentry \times acres)_{ij} + \beta_7(price \times acres)_{ij}. \end{aligned} \tag{3}$$

[6] Acreage weight is the quotient obtained by dividing each respondent's acreage by the largest acreage in each apple and pear dataset.

Equation (3) was estimated separately for direct and indirect valuation. The probability that the respondent will make a particular choice is given by:

$$\text{Prob}\left\{V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik} \text{ for all } k \in C_i\right\}, \tag{4}$$

where C_i is the choice set for individual i. If ε_{ij} are independently and identically distributed across the j alternatives and N individuals with a type I extreme-value distribution, then the probability that the respondent will make a particular choice is estimated using the conditional logit (CL) model:

$$\text{Prob}(j \text{ is chosen}) = \frac{\exp^{V_{ij}}}{\sum_{k \in C} \exp^{V_{ik}}}. \tag{5}$$

The CL approach is limited by the assumption of independence of irrelevant alternatives (IIA) and by model errors being independently and identically distributed across alternatives. Several other approaches relax the IIA assumption in different ways. One approach is the heteroskedastic extreme-value (HEV) model, in which the error variance is allowed to differ across alternatives. In other words, the error terms are assumed to be independent but not identically distributed. Thus the probability of choice is given by:

$$\text{Prob}(j \text{ is chosen}) = \int_{-\infty}^{+\infty} \Pi_{k \in C,\, k \neq j} F\left[\frac{V_j V_k + \varepsilon_j}{\mu_k}\right] \times \frac{1}{\mu_j} f\left(\frac{\varepsilon_j}{\mu_j}\right) d\varepsilon_j, \tag{6}$$

where $F(\cdot)$ is the standard cumulative distribution of the extreme-value distribution, $f(\cdot)$ is the probability distribution of the extreme-value distribution, and μ_j is the scale parameter for alternative j, inversely related to the standard deviation of the error component of alternative j (Louviere, Hensher, and Swait, 2000).

To verify the IIA assumption, we conducted a Hausman test for both apple and pear datasets. Results show that one fails to reject the IIA assumption for the apple dataset ($\chi^2 = 14.82$, p-value$= 0.06$) and the pear dataset ($\chi^2 = 5.23$, p-value$= 0.73$). We also conducted a likelihood ratio test to analyze error variance heteroskedascity; error variances are heteroskedastic for both the apple and pear datasets (apple: $\chi^2 = 7.72$, p-value< 0.05; pear: $\chi^2 = 33.83$, p-value< 0.05). Given these results, the econometric specification used was the HEV. All estimates were calculated using SAS.

WTP for an increase or decrease in the probability of pesticide effectiveness, probability of toxicity for natural enemies, wildlife, and aquatic organisms, and reentry interval levels is obtained by:

$$WTP_m = -\frac{\beta_m}{\beta_{price}}, \tag{7}$$

where WTP_m is WTP for pesticide feature m; m is the probability of pesticide effectiveness, probability of toxicity for natural enemies, wildlife, and aquatic organisms, and reentry interval levels; β_m is the parameter estimate for pesticide feature m; and β_{price} is the parameter estimate for price.

We estimated WTP under direct and indirect valuation approaches. To assess evidence of social desirability bias when eliciting preferences for pesticides features, we compared WTP estimates obtained through direct and indirect valuation by applying the nonparametric combinatorial resampling approach developed by Poe, Giraud, and Loomis (2005). Here we tested the hypothesis that WTP obtained through indirect valuation is higher than WTP obtained via direct valuation for variables that have positive social consequences (nontoxicity for natural enemies, wildlife, aquatic organisms, and reentry intervals).

To measure the prediction accuracy of the direct and indirect formats we used four criteria: (1) comparison of estimated and actual market shares for the commercial pesticides identified by respondents as those used in the 2010 season to control first-generation codling moth in both apples and pears, (2) prediction index, (3) mean square error (MSE), and (4) log likelihood function evaluated at out-of-sample observations (OSLLF).

For the market share comparison, we estimated the actual market share using responses to questions in section two in the questionnaire. The actual market share was calculated by dividing the number of times a pesticide was used by the total number of responses (thirty-five in apples, twenty-six in pears). The predicted market shares were calculated by:

$$\text{Market share}_j = \frac{v_j}{\sum_{l=1}^{L} v_l}, \tag{8}$$

where Market share$_j$ is the share for pesticide j and L denotes all pesticides used last season for codling moth control, V_j is described in expression (3), parameter estimates were obtained from the model, and the values for the probabilities of each choice attribute and price were the average of respondents' perceived values (Option C) weighted by the number of acres owned or operated by each respondent. This market share was estimated using parameters obtained through direct and indirect valuation. Next we compared each predicted market share to the actual shares using the Poe, Giraud, and Loomis (2005) combinatorial resampling approach.

The prediction index indicates the percentage of times the model correctly predicted growers' actual choices or option C. The MSE is the mean of the squared difference between the predicted and actual market share for each pesticide for each valuation approach. The model with the smaller MSE sum across pesticides is more predictive. Norwood, Lusk, and Brorsen (2004) developed the OSLLF criterion. To apply it to our study, we multiplied the actual market share by the natural log of the predicted market share for each pesticide, and then summed this value across pesticides. We replicated this for each valuation approach. The model with the highest OSLLF was more predictive.

Results

Table 4 lists the parameter estimates for the models illustrating the effect of pesticide features on apple and pear growers' pesticide choices. For the apple dataset,[7] the alternative specific constant (ASC) for option C (the status quo option) was statistically significant and negative under indirect valuation. This implies that when asked about other growers' choices, respondents chose the status quo option less often than other alternatives. Controlling for apple operations' acreage, price coefficients were negative and statistically significant, meaning higher prices were associated with a lower probability of choosing a pesticide. The probability of high effectiveness was statistically significant for both direct and indirect valuation, but greater in magnitude under indirect valuation, meaning that respondents believed other growers would care more for pesticide effectiveness than they themselves did. Estimates for the probability of moderate control were positive and statistically significant under both valuation methods. Under direct valuation, the parameter estimate for moderate effectiveness was higher than for high effectiveness. This was not observed when using indirect valuation and might imply that growers prefer a pesticide they have used historically, even if the effectiveness is only moderate, over an unknown pesticide with a stated higher effectiveness. Estimates for the probability that a pesticide would be toxic to natural enemies were negative but statistically significant under direct valuation only. This implies that growers were less likely to choose pesticides that are more toxic to natural enemies. Parameter estimates for the probability of toxicity for wildlife and aquatic organisms were negative but statistically significant under indirect valuation only. This indicates that growers believe that other growers are less likely than they

[7] The apple dataset includes responses from orchard operations and pesticide consultants with an affiliation to an orchard operation. We conducted three different estimations: one for orchard owners only, another for pesticide consultants only, and a third pooling all responses. We obtained more statistically significant estimates and better goodness-of-fit when pooling the two groups of respondents.

Table 4. Heteroskedastic Extreme-Value Model Estimates by Valuation Method for Pesticide Choice

	Apple		Pear	
	Valuation		Valuation	
	Direct	Indirect	Direct	Indirect
ASC 3	0.26	−3.66**	15.21*	−4.14
	(0.34)	(1.51)	(8.08)	(2.73)
Price × Acres	−0.07**	−0.07**	−0.51**	−0.28
	(0.03)	(0.04)	(0.25)	(0.22)
High probability of effectiveness in controlling	1.81*	10.28**	15.15**	89.58**
c. moth × Acres	(1.02)	(2.94)	(7.71)	(45.10)
Moderate probability of effectiveness in	2.69**	7.51**	8.41	78.08**
controlling c. moth × Acres	(1.14)	(2.65)	(6.15)	(39.73)
Probability of toxicity for natural enemies × Acres	−1.95**	−1.99	−20.37*	−9.45
	(0.89)	(1.64)	(10.29)	(6.44)
Probability of toxicity for wildlife × Acres	−1.25	−4.62**	−4.17	−7.16
	(0.92)	(2.23)	(5.02)	(8.65)
Probability of toxicity for aquatic organisms × Acres	−0.93	−3.22**	−0.17	−5.57
	(0.85)	(1.63)	(3.61)	(4.10)
Reentry interval × Acres	−0.21**	−0.30*	−0.97	−2.45*
	(0.08)	(0.12)	(0.62)	(1.38)
Scale	0.97*	0.23**	0.04**	0.02*
	(0.58)	(0.08)	(0.02)	(0.01)
Log-likelihood	−268.54	−279.81	−115.15	−99.07
Number of observations	280.00	280.00	208.00	208.00

Notes: Numbers in parentheses are standard errors. One and two asterisks (*, **) denote statistical significance at the 5 % and 10 % level.

themselves are to buy a pesticide toxic to wildlife and aquatic organisms. Estimates for reentry interval were negative and statistically significant under both valuation approaches, indicating that longer reentry intervals would negatively affect growers' pesticide choices. The estimate for the scale or error variance was positive and statistically significant, signaling error variance differences across alternatives.

For the pear dataset, the alternative specific constant for option C was positive and statistically significant under direct valuation. This indicates that respondents favored the status quo pesticide choice over the other two options presented. That pear growers showed a stronger preference for the status quo might be a result of the high risks implied in pest control influencing growers' choice of pesticide option.[8] Controlling for operation acreage, the parameter estimates for prices were negative and statistically significant only under direct valuation. This implies that higher prices would lead to a lower probability of choosing a pesticide. Estimates for the probability of high and moderate effectiveness in controlling codling moth were positive and statistically significant for both valuation methods (except the moderate effectiveness under direct valuation). For pear growers, high efficacy in controlling pests appears to be crucial when selecting a pesticide. The magnitude of the

[8] Marsh, Mkwara, and Scarpa (2011) argue that the status quo bias could be attributed to loss aversion, cognitive misperceptions and regret avoidance, protesting, and choice task complexity. Also, respondents might tend to avoid the cognitive burden associated with evaluating the choice task alternatives that they have not experienced, or the alternatives presented seemed unattractive to respondents. Thus, they were more likely to choose the status quo. Marsh, Mkwara, and Scarpa (2011) found that respondents who adopted their own perceived status quo scenario expressed a higher WTP for improvements across attributes subject to their study. However, this tendency was lessened by a general reluctance to embrace policy options implying changes from the status quo, about which they had good knowledge. In our case, the status quo did not imply a perceived higher quality than the levels of the pesticide options provided. Due to the risk involved in fruit production, growers seem to prefer pesticides they have experienced, as they know these work under their own production conditions. Thus, they might prefer to remain with the known pesticide option.

Table 5. Willingness to Pay (WTP) for Pesticide Features Used in Apples and Pears Obtained through Direct and Indirect Valuation

	WTP Apple Growers			WTP Pear Growers		
	Valuation			Valuation		
WTP for Having a Pesticide That Is	Direct ($/acre)	Indirect ($/acre)	Difference (p-values)[a]	Direct ($/acre)	Indirect ($/acre)	Difference (p-values)[a]
Highly effective in controlling c. moth	24.14 (171.31)	137.43 (2219.59)	0.08	29.78 (4054.46)	316.43 (7552.85)	0.12
Moderately effective in controlling c. moth	35.96 (286.98)	100.39 (1675.64)	0.19	16.54 (6950.91)	275.80 (7007.72)	0.12
Nontoxic for natural enemies	26.03 (162.02)	26.60 (582.62)	0.48	40.06 (3515.80)	33.37 (733.07)	0.33
Nontoxic for wildlife	16.62 (90.58)	61.83 (427.67)	0.86	8.20 (4005.99)	25.28 (440.06)	0.72
Nontoxic for aquatic organisms	12.39 (31.53)	43.10 (918.66)	0.83	0.34 (1883.62)	19.68 (484.59)	0.85
With one day less of reentry interval	2.76 (9.53)	3.99 (84.04)	0.63	1.91 (231.72)	8.64 (190.29)	0.86

Notes: Numbers in parentheses are standard deviations determined via parametric bootstrapping.
[a] P-values represent the p-value of a one-sided test of indirect valuation WTP > direct valuation WTP. The one-sided p-value of direct valuation WTP > indirect valuation WTP is simply 1 minus the p-value reported in the table. A two-sided test for statistical differences is simply 2 times the p-value reported in the table (Poe, Giraud, and Loomis, 2005).

indirect valuation coefficient for effectiveness was higher compared to direct valuation, indicating that respondents believe that control efficacy would be more important for other growers than for themselves. The estimate for the probability of pesticide toxicity to natural enemies was negative and statistically significant only under direct valuation. This signals that the more toxic a pesticide was for natural enemies, the less likely that growers would choose it. Estimates for the probability of toxicity for wildlife and aquatic organisms were not statistically significant under either valuation method. The estimate for the reentry interval was negative and statistically significant only under indirect valuation. This implies that the longer the reentry interval, the less likely pear growers would choose it.

Table 5 presents WTP to increase the probability of pesticide effectiveness; decrease the probability of toxicity for natural enemies, wildlife, and aquatic organisms; and increase the reentry interval by one day. It also reports the standard deviations for each WTP that were calculated through parametric bootstrapping following the Krinsky and Robb (1986) procedure. Table 5 also lists the combinatorial differences (p-values) between WTPs obtained through direct and indirect valuation. A p-value less than 0.05 indicates that the WTP obtained through indirect valuation is greater than the WTP obtained through direct valuation.

Apple growers stated a WTP of $26.03 per acre under direct valuation and $26.60 per acre under indirect valuation to decrease the probability of a pesticide being toxic to natural enemies. However, there were no statistically significant differences between the WTPs obtained through direct and indirect valuation for any of the features. Thus, we reject the hypothesis that variables with a socially positive connotation exhibit indirect valuation WTP higher than direct valuation WTP.

For pear growers, the WTP to decrease the pesticides' probability of toxicity for natural enemies was estimated at $40.06 per acre under direct valuation and $33.37 per acre under indirect valuation. Similar to apple growers, there was no evidence of social desirability bias, as there were no statistically significant differences across WTPs obtained via the two approaches.[9] Choices made by profit-maximizing decision makers might not be aligned with social desirability manifestations. Despite all the potential effects to workers' health and environment, pesticide choice seems to be a socially neutral phenomenon. Growers are aware that they all face similar risk aversions to pest infestations. Thus, pesticide effectiveness is the main concern when choosing a pesticide. In addition, strong regulations of pesticide use and the phaseout of pesticides with potential negative effects might have influenced growers' perceptions.

Validation of Results

Table 6 reports actual and predicted market shares for seven commercial pesticides used in apples and pears. For apples, actual market share indicated that Altacor, Delegate, and Guthion were the preferred pesticides. Predicted market share obtained through direct and indirect valuation showed that Intrepid and Assail were preferred. For pears, actual market share indicated that Altacor and Delegate were preferred, while predicted market shares obtained through direct valuation showed that Calypso and Guthion were preferred. Predicted market shares obtained through indirect valuation showed that Calypso and pheromones were preferred.

Table 6 also lists results from the combinatorial differences across actual and predicted market shares. For pesticides used in apple orchards, there were no statistically significant differences between the actual and predicted market share obtained through direct valuation for Assail, Cyd-X, Intrepid, and Rimon. For the predicted market share obtained through indirect valuation, there were no statistically significant differences for Assail and Intrepid. This shows slight prediction superiority for market shares obtained via direct valuation. For pesticides used in pear orchards, there were no statistically significant differences between the actual and predicted market shares obtained through direct valuation for Calypso and Cyd-X. For market shares obtained through indirect valuation, there were no statistically significant differences for Calypso, Guthion, and pheromones. This result indicates slight prediction superiority for market shares obtained through indirect valuation. Prediction accuracy for both direct and indirect valuation was far from stellar. Recall that to calculate predicted market shares we used growers' responses on their perceptions of the pesticide used to control for first-generation codling moth. Results implied that growers' perceptions and actual choices for a pesticide were not aligned with preferences for different pesticides' features when these are evaluated in a disaggregated way.

Results for the prediction index, MSE, and OSLLF are presented in table 7. For the apple dataset, direct valuation had higher prediction accuracy when using all three criteria. For the pear dataset, the prediction index and the OSLLF favored indirect valuation, while the MSE did not. The MSE was affected by one large deviation in the predicted market share of pesticide Calypso that noticeably increased the MSE sum.

That indirect valuation predicted market shares slightly better in the pear dataset relative to the apple dataset could be explained by the fact that apple and pear production conditions are different. Pear growers face greater challenges than apple growers in pest control, requiring a greater investment in pesticide applications. This could lead to different perceptions of how growers themselves control pests and how they believe others control pests. Pear growers' beliefs about how others control pests are closer to actual practices than their beliefs about how they themselves control pests. Pear growers' belief that other growers care more than they themselves do for control effectiveness seems to have the biggest influence on results favoring the prediction accuracy of

[9] We also conducted pairwise t-tests comparisons between WTP obtained through direct and indirect valuation. For the apple dataset, we found statistically significant differences for the probability of reducing toxicity only for wildlife. For the pear dataset, there were statistically significant differences between direct and indirect valuation of the WTP for the probability of high effectiveness in controlling codling moth and reentry interval. Hence, we found no compelling evidence of statistically significant differences between WTP obtained through either approach for both apples and pears.

Table 6. Comparison between Actual and Predicted Market Share for Seven Commercial Pesticides Used in Apples and Pears

		Direct Valuation		Indirect Valuation	
Pesticide	Actual Market Share (%)	Predicted Market Share (%)	Difference between Actual and Predicted Market Share (p-value)	Predicted Market Share (%)	Difference between Actual and Predicted Market Share (p-value)
Apples					
Altacor	42.86	1.63	0.00	0.01	0.00
		(3.30)		(0.09)	
Assail	11.43	31.99	0.50	16.89	0.25
		(36.80)		(32.17)	
Cyd-X	5.71	4.63	0.15	0.23	0.01
		(12.93)		(3.49)	
Delegate	14.29	0.52	0.01	0.00	0.00
		(4.99)		(0.03)	
Guthion	14.29	0.61	0.01	0.30	0.00
		(7.43)		(5.35)	
Intrepid	5.71	58.04	0.79	82.24	0.93
		(40.05)		(32.81)	
Rimon	5.71	2.58	0.13	0.32	0.01
		(6.02)		(2.90)	
Pears					
Altacor	38.46	0.88	0.00	2.09	0.01
		(2.79)		(7.95)	
Assail	7.69	1.28	0.02	1.76	0.03
		(9.68)		(11.20)	
Calypso	3.85	69.72	0.86	87.21	0.95
		(39.01)		(26.68)	
Cyd-X	3.85	6.07	0.14	1.24	0.02
		(19.91)		(10.20)	
Delegate	34.62	0.30	0.00	1.04	0.01
		(3.16)		(6.98)	
Guthion	3.85	20.98	0.04	2.15	0.36
		(35.28)		(12.49)	
Pheromone	7.69	0.76	0.02	4.51	0.15
		(3.10)		(11.00)	

Notes: Numbers in parentheses are standard deviations determined via parametric bootstrapping.

indirect valuation. This also indicates that pesticide effectiveness is the main concern for pear growers.

Conclusions

We used a hypothetical discrete choice model to measure apple and pear growers' valuation for pesticide features that conserve natural enemies in the orchard. We applied the indirect valuation approach to remove potential wedges between stated values for pesticides in a hypothetical survey and actual values. This paper first measured growers' WTP for conserving natural enemies in the orchard and found that apple growers stated a WTP of $26.03 per acre under direct valuation and $26.60 per acre under indirect valuation to decrease the probability of toxicity to natural enemies.

Table 7. Prediction Accuracy for the Estimates Obtained via Direct and Indirect Valuation

	Direct Valuation	Indirect Valuation
Apples		
Prediction index[a]	91.43	10.00
MSE[b]	0.525	0.818
OSLLF[c]	−3.79	−7.32
Pears		
Prediction index[a]	73.08	82.21
MSE[b]	0.73	0.95
OSLLF[c]	−4.72	−3.94

Notes: [a] Indicates the number of times the model accurately predicted actual pesticide choices; a higher number implies better prediction.
[b] Mean square error between actual and predicted market share; a lower number implies better prediction.
[c] Out-of-sample log likelihood function, considering actual and predicted market share; a higher number implies better prediction.

Pear growers stated a WTP of $40.06 per acre under direct valuation and $33.37 per acre under indirect valuation.

The second objective of this paper was to assess evidence of social desirability bias in apple and pear growers' preferences for pesticides features. Neither apple nor pear growers offered any statistically significant differences between either valuation approach. These results contrast with previous findings (Lusk and Norwood, 2009a,b; Olynk, Tonsor, and Wolf, 2010; Norwood and Lusk, 2011) that investigated choices made by utility-maximizing consumers and found higher WTP for variables with positive social influence. In contrast, the choice investigated here is made by profit-maximizing producers. The difference in decision-making agents sets our investigation in a different context. List (2006) claimed that the potential to reduce social desirability biases when using an indirect valuation approach depends on the problem context. Pesticide choices made by profit-maximizing growers might not be the context in which to observe social desirability bias. The need to protect crops from pest damage, rather than pressure to respond according to social norms, is the main reason for pesticide choice.

To validate our results, we compared actual and estimated market shares for the pesticides commonly used in apple and pear orchards to control first-generation codling moth and found differences between apple and pear growers. For the apple dataset, direct valuation exhibited higher prediction accuracy, while for the pear dataset, indirect valuation had higher prediction accuracy. These findings underscore the importance of understanding problem context. Apple and pear growers experience dissimilar growing conditions, yet both groups must protect crops from pests. They are also presented with varying degrees of production, financial, and marketing risk, creating a context in which respondents' stated choices show no evidence of departing from actual behavior as a result of social desirability sentiments.

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